Basinwide Conditions

CHAPTER 3

BASINWIDE CONDITIONS

SECTION 3.1 INTRODUCTION

Conditions in Hylebos Creek and the Lower Puget Sound basins stem from many interacting factors. Primary among them is the intense land use patterns that generate high volumes of poor quality stormwater to stream systems. When stormwater discharges interact with the stream systems, soils, geology, and habitat in the basins, it profoundly impacts the drainage capacity of these systems, stream channel erosion, sedimentation, habitat conditions, wildlife populations, and groundwater volumes.

This chapter details these land use and stormwater discharge impacts in the planning area as a whole from seven disciplinary perspectives, as follows: Geology (3.2), Hydrology (3.3), Flooding (3.4), Groundwater (3.5), Erosion and Sedimentation (3.6), Water Quality (3.7), and Habitat (3.8). Public/Private Sector Actions and Future Directions (3.9) describes the regulatory and other human factors that underlie the physical conditions. The content of each of these sections is summarized in Chapter 2.2., Review of Report Contents.

SECTION 3.2 GEOLOGY

INTRODUCTION

The Hylebos Creek and Lower Puget Sound basins encompass a variety of geologic terrains. These terrains dramatically influence patterns of surface-water runoff, groundwater flow, and hillslope stability. Long an area of limited population and development activity, rapid growth in the last two decades has resulted in increased concern for the impacts of that development on the land and the constraints that are in turn imposed on human activity. This geologic study provides an overview and a framework for both basinwide streamflow patterns and area-specific hazard evaluation.

DATA SOURCES

This study follows decades of local investigations, initiated by U.S. Geological Survey publications covering all but the most western and southern parts of the area (Waldron, 1961, 1962). Field work for the present study spanned 1988 and early 1989, involving site inspection of all shoreline exposures, all stream channels, and innumerable roadcuts and building excavations throughout the upland areas. Not surprisingly, the distribution of mapped deposits follows closely on the equally detailed work of earlier studies; yet access and exposures have improved dramatically in the last three decades, permitting greater certainty and refinement in identifying geologic materials and the interpretation of their history. Additional data was obtained from well log reports in the vicinity of the Midway Landfill (Applied Geotechnology, 1988), along the coastline (Department of Ecology, 1979), and detailed groundwater investigations in the Federal Way area (Robinson and Noble, written communications, 1988).

CONDITIONS

Physiography

The Hylebos and Lower Puget Sound basins drain an elongated upland plateau known as the Des Moines Drift Plain, bounded on the west by Puget Sound, the east by the Green-Puyallup valley, and the south by the Puyallup River floodplain and (now-filled) estuary. Hylebos Creek drains south over the surface of the drift plain, incising through the surface deposits to reveal the underlying geologic materials only in the lower reaches of the East Branch. In contrast, the Lower Puget Sound drainages have carved rapidly through the lip of the uplands, reflecting their greater steepness and thus greater competence for erosion. Wave action along the shores of Poverty Bay maintains a steep shoreline bluff in many areas and has probably caused significant steepening of these basins by bluff retreat, active since deglaciation of the region about 14,000 years ago.

Glacial History and Stratigraphy

Glacier ice originating in the mountains of British Columbia has invaded the Puget Lowland several times, leaving a discontinuous record of early to late Pleistocene glacial and interglacial periods (Easterbrook, 1986). The ice was part of the Cordilleran ice sheet of northwestern North America; it advanced into the Lowland as a broad tongue referred to as the "Puget lobe" by many authors since Bretz (1913).

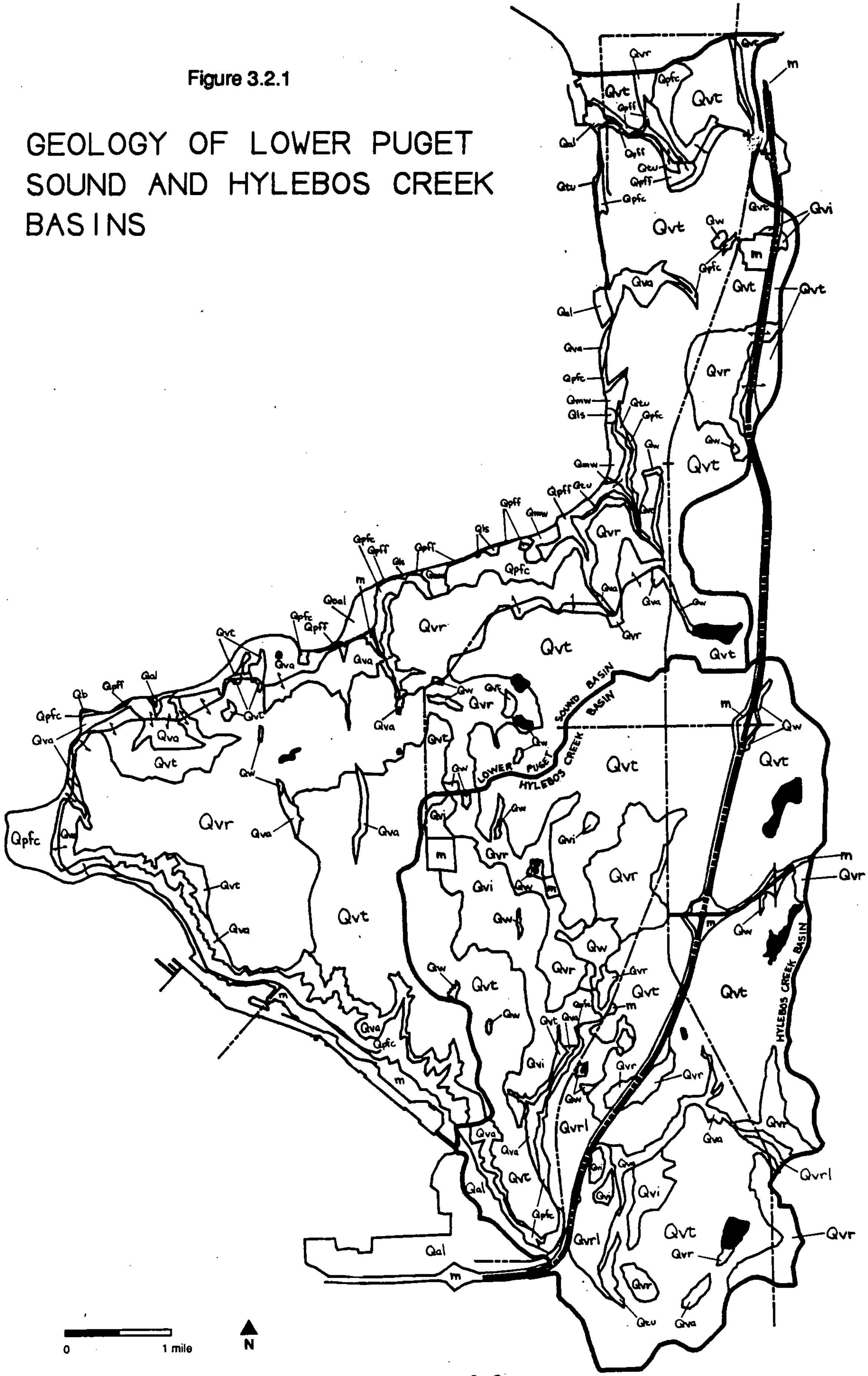
In the study area, deposits of at least two and possibly three glaciations are exposed (Figure 3.2.1). Most widespread are those from the most recent ice advance and retreat, named the "Vashon" by Armstrong and others (1965) because of particularly good exposures on Vashon Island. These deposits underlie the upland plain, now truncated by Puget Sound to the west and the Green River valley to the east.

The most common surficial deposit of Vashon age is till, a compact mixture of silt, sand, and gravel deposited at the base of the glacier. Overlying the till and covering large areas of the southwestern and south-central planning area are broad areas of recessional outwash. These are mainly sand and gravel deposited by rivers emerging from the margin of the retreating ice. The position and surface altitudes of this outwash suggest simultaneous deposition with the extensive outwash terraces in the Soos, Jenkins, and Covington Creek basins some 10-20 miles (15-30 km) east (Mullineaux, 1970; Booth, 1989). Flow of these glacial torrents, controlled and diverted by the position of the steadily retreating glacier margin, was probably south and then across the planning area, draining southwest into what is now Commencement Bay.

Outwash deposited earlier, during advance of the ice sheet, underlies the till and is present throughout the area. In general, however, it is identified most often in well logs; but these advance outwash deposits are well exposed at the ground surface along the northwest- and southwest-facing slopes above Puget Sound and in the incised valleys of Joes Creek and East Branch Hylebos Creek. At Dumas Bay, the Vashon advance outwash is exposed at sea level along 1.5 miles of coastline. This exposure is part of a sub-sea-level channel that extends north through Maury Island and east-central Vashon Island (Booth, in press) and back on to the mainland at Point Pully (3 miles north of the study area; Waldron, 1962). In the south, the channel is traced by numerous water-supply wells, forming the "Milton-Redondo Channel" that yields much of Federal Way's water

Figure 3.2.1

GEOLOGY OF LOWER PUGET SOUND AND HYLEBOS CREEK BASINS



DESCRIPTION OF MAP UNITS (FIG 3.2.1)

HOLOCENE DEPOSITS

POSTGLACIAL DEPOSITS (HOLOCENE) - Divided into:

Modified Land (m)

Beach Deposits (Qb)

Wetland Deposits (Qw)--Localities are compiled from the King County Wetland Inventory (1983).

Alluvium (Qal)

Landslide Deposits (Qls)--Only four are sufficiently large to show at map scale; smaller such features are common along many of the wave-steepened beach cliffs.

Mass-Wastage Deposits (Qmw)--Colluvium, soil, or landslide debris with indistinct morphology, mapped where sufficiently continuous and thick to obscure underlying material.

Older Alluvium (Qoal)--Similar in texture and morphology to unit Qal. May represent a late stage of deposition during the time of Vashon ice recession.

PLEISTOCENE DEPOSITS

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION (PLEISTOCENE) - Divided into:

Recessional Outwash Deposits, Lacustrine (Qvrl)--Laminated to massive silty clay to clayey silt, deposited in standing water during a late stage in the ice recession.

Recessional Outwash Deposits, Undifferentiated (Qvr)--Stratified sand and gravel, moderately to well sorted, with less common silty sand and silt.

Ice-Contact Deposits (Qvi)--Similar in texture to unit Qvr but containing a much higher percentage of silt mixed in with the granular sediment.

Till (Qvt)

Advance Outwash Deposits (Qva)

PRE-FRASER DEPOSITS (PLEISTOCENE)- Divided into:

Pre-Fraser Deposits, Fine-Grained (Qpff)--Laminated to massive silt, clayey silt, and silty clay, with or without interbedded sand and uncommon gravel.

Pre-Fraser Deposits, Coarse-Grained (Qpfc)--Interbedded sand and gravel with at most minor layers and lenses of silty sand and silt; moderately to heavily oxidatidized. Weathering rinds are common but not ubiquitous and range from 0.1-0.3 mm on fine-grained volcanic clasts.

Till, Undifferentiated (Qtu)--Compact, stony diamict, distinguished from its Vashon-age equivalent by oxidation of clasts and matrix, rare weathering rinds on clasts up to 0.5 mm thick, and stratigraphic and topographic position. Includes fluvial, lacustrine, and mudflow deposits too thin to discriminate at map scale.

supply. Its altitude suggests that it may mark a pre-Vashon river valley, estuary, or arm of Puget Sound, offset several kilometers from the present-day location of the waterway in this area.

In addition to recessional outwash deposits of sand and gravel, recessional deposits of silt and clay are also present in the basin plan area. They are concentrated in the Lower Hylebos sub-basin, where they lie at elevations below about 100 feet. These deposits reflect the last stage in the ice recession, when the immediate area was ice-free but the wasting glacier still blocked the northward drainage of lowland rivers out of Puget Sound. As a result, regional lakes formed until the impounded water could spill south into the Chehalis River valley (Thorson, 1980). Deposition into these lakes was limited here to fine sediment, which now forms a low-lying area bounded on the east and west by till-mantled hills and truncated on the south by more recent alluvium of the Puyallup River.

Pre-Vashon glacial advances are expressed by discontinuous, near sea-level till exposures along the shores of Poverty Bay and near Milton; a till lens exposed in the Redondo area at about altitude 150'; and thick, widespread deposits of oxidized sand and gravel that apparently underlie most if not all of the basin plan area at depth. These river-lain deposits are interpreted here as having a glacial origin because deposits of equivalent coarse texture, mixed lithologies, great thickness, and lateral extent are not being deposited in the modern (non-glacial) landscape but are common throughout sediments of unequivocal glacial (namely Vashon) origin and age.

Regional Correlations

Correlation of these pre-Vashon glacial deposits with formally named units farther east (Crandell and others, 1958) or north (Easterbrook and others, 1967) is problematic. The type area for the Salmon Springs Glaciation (Crandell and others, 1958) lies over 6 miles (10 km) to the southeast along the east wall of the Puyallup River valley and has been dated at greater than 750,000 years old (Easterbrook and others, 1981). A layer of air-borne volcanic ash has permitted correlation of this deposit across to the west wall of the Green River valley near Peasley Canyon (Westgate and others, 1987), only a few miles east of the study area. Superficially, these named deposits are similar to those found throughout the study area. Were this correlation correct, however, it would require that the several intervening glaciations that occurred between 750,000 and 15,000 years ago (e.g., Easterbrook and others, 1967; Lea, 1984; Booth, 1990) would have left no record of their passage. Over so broad an area, such a widespread absence of deposits seems implausible. Thus no correlation of these earlier glacial deposits are made in this report with formally named deposits elsewhere in the Puget Sound region. This problem has also been recognized farther south (Noble, 1990).

CONSEQUENCES FOR DRAINAGE-BASIN CONDITIONS

This geologic setting has several consequences for land use, hydrology, and stream-channel erosion and deposition in the Hylebos and Lower Puget Sound basins. Overall, the deposits form a crude 4-element sequence: locally thick and permeable deposits of Vashon recessional outwash or ice-contact deposits, overlying thin and relatively impervious Vashon till, overlying sand and gravel of either the Vashon advance outwash or other older glacial outwash, overlying a yet-older mixture of clay or till or other impervious sediment. This sequence results in several widespread conditions in the basin plan area (with locations of examples noted in parentheses):

- Landslide susceptibility at and near the contact between the lowermost till/clay deposits and the overlying sand and gravel, caused by the perching of groundwater above this contact and the resultant reduction in slope stability (examples are found throughout the region, but a particularly spectacular one is located above the shores of Poverty Bay, northeast of SW 295th Street between about 8th and 10th Avenue SW);

- Highly erodible stream channels where they pass over the sand and gravel deposits that underlie the Vashon till, because of the lack of either cohesion or coarse sediment in that middle layer (the lower East Branch Hylebos Creek, particularly just above its confluence with tributary 0016);

- Highly infiltrative soils resulting in low or absent surface-water runoff, particularly where thick undisturbed deposits of the recessional outwash are exposed at the ground surface (closed infiltrative depressions west and northwest of Panther Lake, where not impacted by recent construction activity);

- Excellent bearing strength for construction of most of the upland area underlain by Vashon till, coupled with a moderately high potential for release of fine sediment into the stream system during construction activity (the entire Federal Way commercial area bounded by I-5, Steel Lake, Mirror Lake, and Kitts Corner); and

- Widespread areas of wetlands and wetland soils, associated either with shallow groundwater perched on top of the nearly level, undulating till surface, or with Vashon recessional lake-bottom sediments ("Spring Valley", at and just above the confluence of the north fork and West Branch of Hylebos Creek near the County line).

SECTION 3.3 HYDROLOGY

INTRODUCTION

The hydrologic processes in the Hylebos and Lower Puget Sound basins have been severely altered from historic conditions in most areas and are anticipated to be further affected as urbanization continues. Understanding the hydrologic processes that are affected by land-use alterations provides the basis for solving existing and future flow-related problems.

This section discusses hydrologic concepts that influence runoff in the basins, followed by a description of the hydrology of the basins under 1987 land use, future build-out conditions, and pre-developed conditions.

HYDROLOGIC CONCEPTS

Hydrologic Characteristics

Simulating the hydrology of the Hylebos Creek and Lower Puget Sound planning area required grouping soils, topographic slope, and land cover into hydrologically similar categories. This sub-section describes the characteristics of each of these groups.

Soils - Soils were placed into three broad categories: outwash, till, and wetlands (see Section 3.2, Geology, for a complete discussion of soils). Outwash soils consist of sand and gravel deposits that have high infiltration rates. Rainfall in these areas is quickly absorbed and percolates to the groundwater table. Creeks draining these areas typically intersect the groundwater table and receive most of their flow from groundwater discharge, unless they are located in a part of the deposit located above the water table. The response in the creeks after a storm is therefore slow, with the peak flow in the creek often occurring up to several days after a storm.

Till deposits contain large percentages of silt or clay and have low percolation rates compared to the outwash deposits. Only a small fraction of the infiltrated precipitation percolates to the groundwater table. The rest moves laterally through the thin surface soil above the till deposit, often re-emerging at the base of hillslopes. This shallow, subsurface, lateral movement of flow is called interflow. Interflow travels to the creek much faster than groundwater but slower than surface runoff. Soils overlying till deposits may become saturated in large storms and produce significant amounts of surface runoff. The peak runoff rate from till areas is therefore typically much higher than from outwash areas.

Wetland soils remain saturated throughout much of the year. The hydrologic response from wetlands is variable depending on the underlying geology, the proximity of the wetland to the regional groundwater table, and the bathymetry of the wetland. Generally, wetlands absorb runoff in the summer months if they are located above the groundwater table and release groundwater to the creek if it intersects the groundwater table. In winter surface flows are attenuated via hydraulic storage and slow release when soils are saturated.

Land Cover - Three types of cover were considered in analyzing the hydrology of the Hylebos Creek and Lower Puget Sound basins: forest, grass/pasture, and impervious.

Runoff from forested areas produces the least amount of surface runoff. Forest cover is most significant in till areas because it breaks up the structure of the till and its thin surface soils and allows for more infiltration to occur. Interception and evapotranspiration, a factor in most autumn, spring, and summer storms, is also greater in forested areas than with the other cover categories.

Grassed areas produce more surface runoff than forested areas because grass is shallow rooted and does not contribute to infiltration as forested cover does. Grassed areas therefore saturate quicker and produce more overland flow in large storms than forested areas.

Impervious areas produce the most surface flow of all cover categories. The infiltration rate in impervious areas is zero; therefore, precipitation runs directly off to produce high peak flows.

The combination of forest cover on outwash produces the lowest peak flows, with grass-covered outwash producing the next lowest, then forested till, grassed till, and finally impervious cover. Peak flows from wetland soils are variable depending on the characteristics of the wetland and the time of year.

Stream Channels, Lakes, and Wetlands - Receiving creeks, lakes, and wetlands also affect the runoff characteristics from a given area. These features store flows and release them slowly, thus reducing the flow peak. The degree to which these flows are reduced depends upon the roughness, slope, size, and shape of the channel. The most sensitive of these parameters is channel size. Thus, wetlands and lakes by virtue of their larger storage volume are typically more effective than channels at reducing flow peaks.

Slopes - Slopes in till areas were grouped into three broad categories: 0-5 percent, 5-15 percent, and greater than 15 percent. Slopes influence the rate at which interflow discharges to the creek in till soils. Steeper slopes have faster interflow responses than flatter slopes. This allows the thin surface soil in steeper sloping till areas to drain faster than flat sloped till. Because the flat sloped till areas do not drain as well, the soil saturates more quickly in large storm events, producing more significant surface runoff.

HSPF Hydrologic Model

The hydrology of the planning area was analyzed using the Hydrological Simulation Program-Fortran (HSPF) computer model. This model uses mathematical relationships to describe the physical processes controlling the hydrology of the watershed. Using inputs of precipitation and evaporation, HSPF computes the amount of discharge to the creek continuously through time from surface, interflow, and groundwater flow.

The HSPF model was calibrated using two years of stream flow and precipitation records collected by the U.S. Geological Survey (USGS) within the basin for water years 1987-1988. Regionalized calibration parameters developed by the USGS (Dinicola, 1989) initially were used and then refined to better match the conditions in the Hylebos Creek and Lower Puget Sound basins. Using the calibrated model, a 39-year continuous record of rainfall collected at the Seattle-Tacoma Airport station was input to create a 39-year series of flows at the outlet of each of the 60 subcatchments in the planning area (Figures 3.3.1a and b). Three different land-use scenarios were modeled: 1) Current (1987), 2) future (build-out under existing (1987) zoning and County land-use plans), and 3) pre-developed (forested).

CONDITIONS

Current (1987) Conditions

Land Cover - Simulated flows for the current land-use scenario are based on conditions in 1987 (also used to calibrate the hydrologic model). Table 3.3.1 provides a summary of commercial and residential land uses tributary to each stream outlet. Figures 3.3.2a-e depict 1987 land cover tributary to the outlet of the major creeks. In general, a larger percentage of the land area in the Lower Puget Sound basin has been developed with approximately 30 percent remaining forested as compared to the Hylebos Creek basin where over 50 percent of the basin remains undeveloped under 1987 conditions. The percentage of impervious surface in the West Branch Hylebos sub-basin is comparable to the percentage of impervious surface in the Lower Puget Sound basin, despite the lower level of overall development in the West Branch Hylebos Creek sub-basin. This indicates a much higher density of development, where it occurs, in the West Branch Hylebos Creek sub-basin.

Table 3.3.1

SUMMARY OF (1987) LAND USES TRIBUTARY TO EACH BASIN OUTLET

BASIN	1987 LAND USE (ACRES) COMM.	MULTI-FAMILY	3-7 UNITS/AC	1-3 UNITS/AC	RURAL
West Hylebos	832.4	225.5	613.9	0.0	249.7
East Hylebos	217.6	83.4	791.8	0.0	156.3
McSorley Creek	201.4	141.2	730.6	0.0	19.1
Woodmont Creek	20.2	9.9	161.4	0.0	16.3
Redondo Creek	57.8	46.8	296.8	0.0	0.0
Cold Creek	55.5	37.4	206.9	0.0	0.0
Lakota Creek	82.2	160.0	1045.3	0.0	49.8
Joes Creek	47.2	23.4	802.6	0.0	37.4

Flow Frequencies by Basin - Flows produced by the continuous HSPF model over the 39-year simulation period were used to compute return frequencies for peak annual flows. A Log-Pearson analysis, based on Water Resources Council guidelines (WRC, 17a, 1977) was used to compute the magnitude of peak annual flows over a range of return periods of 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500 years. Flows for the 2-, 10-, 25-, and 100-year flows at the outlet of each

Figure 3.3.1a

Hylebos Creek Basin Planning Area

SUB-BASINS IN THE HYLEBOS CREEK BASIN

West Branch Hylebos

Lower Hylebos

East Branch Hylebos

WH12 Subcatchment Number

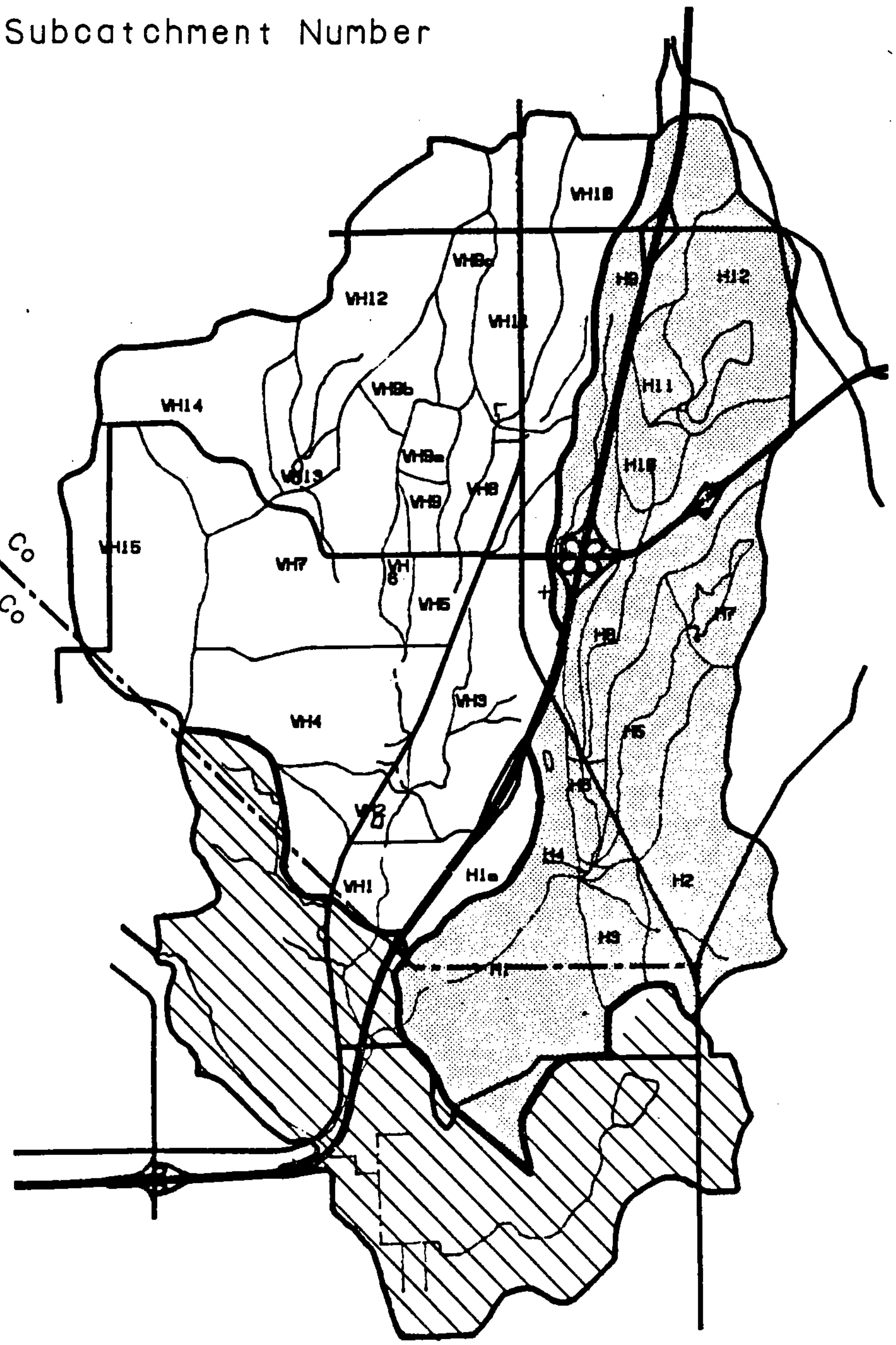


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Figure 3.3.1b

Lower Puget Sound Basin

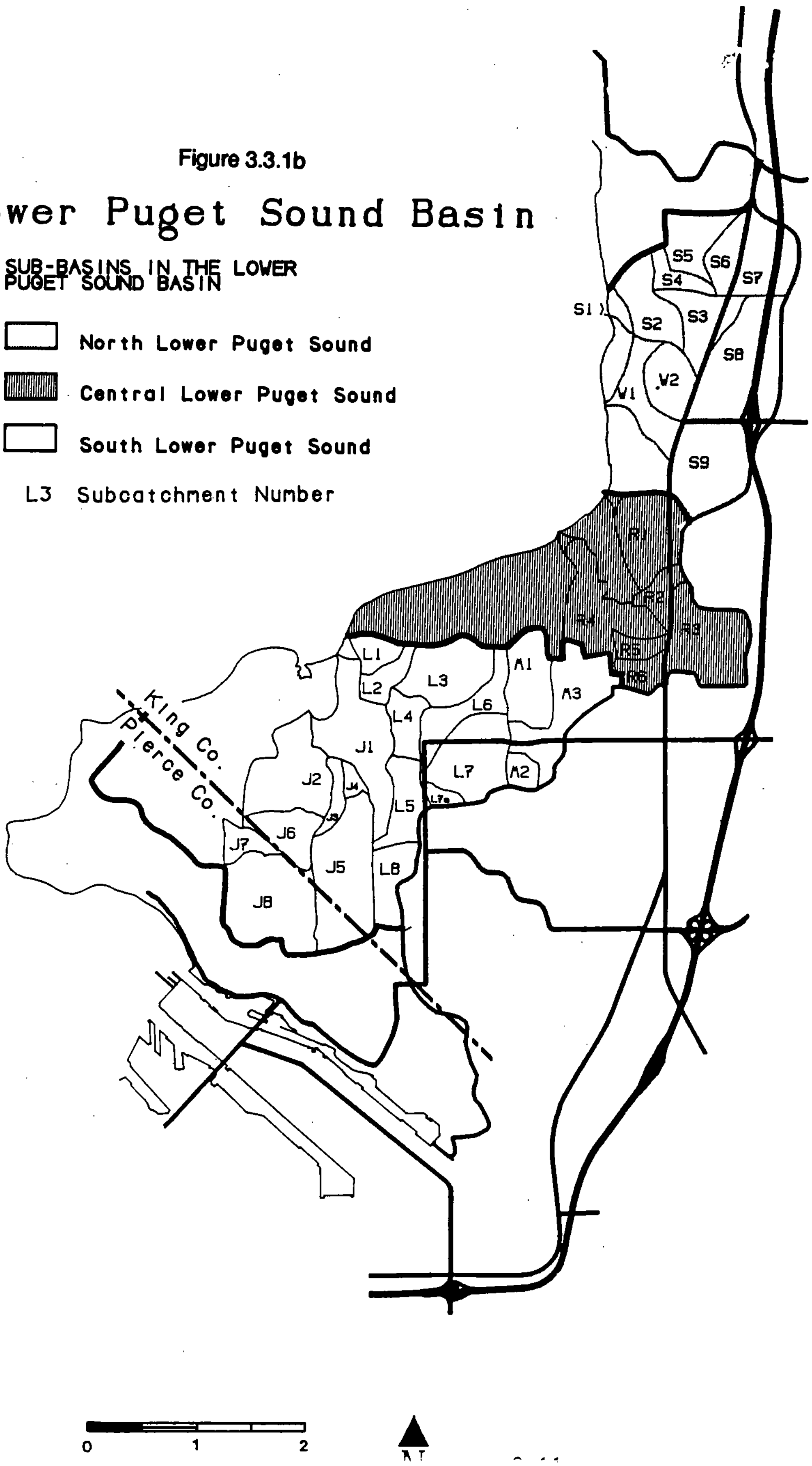


FIGURE 3.3.2a 1987 LAND COVER

West Branch Hylebos Creek Sub-basin

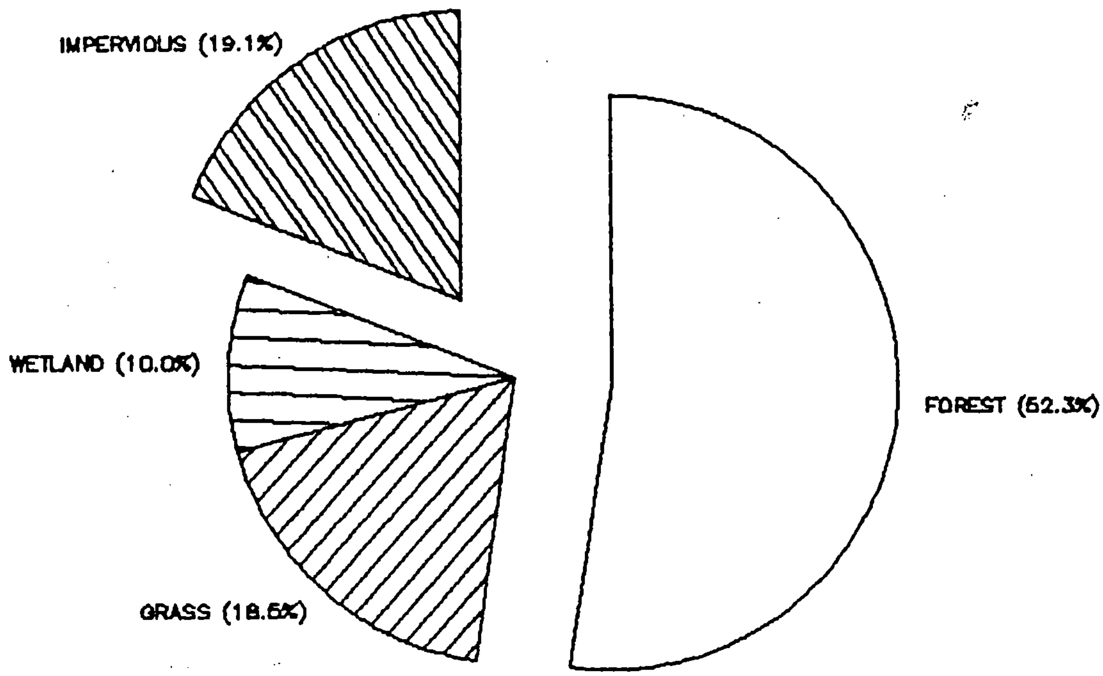


FIGURE 3.3.2b 1987 LAND COVER

East Branch Hylebos Creek Sub-basin

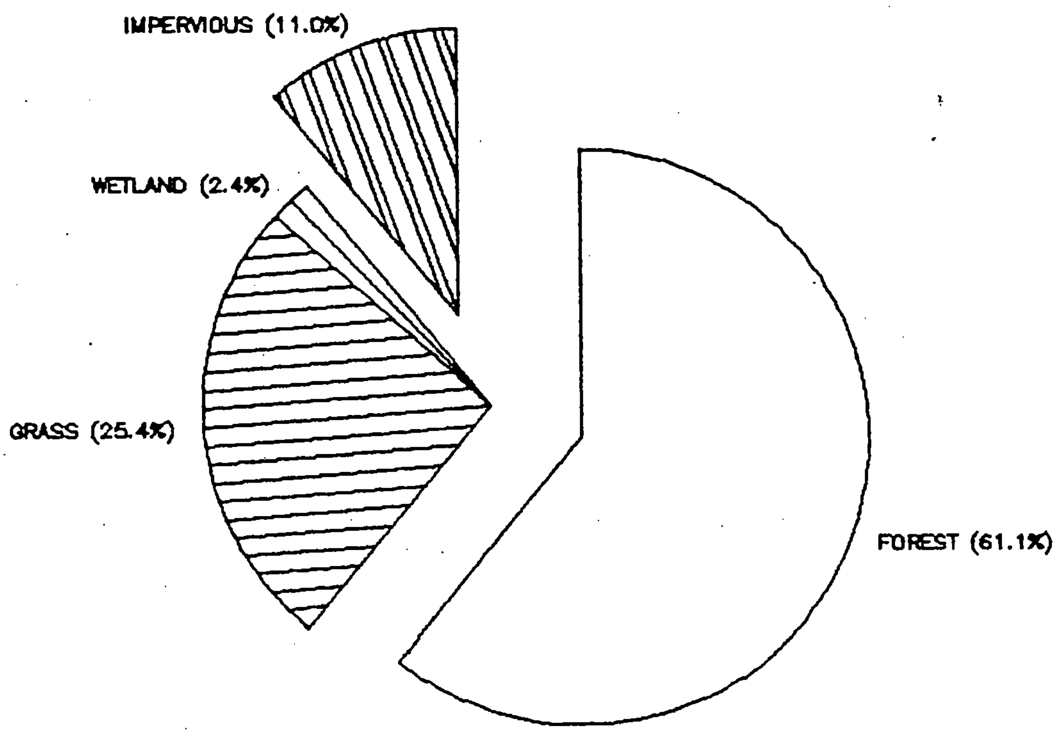


FIGURE 3.3.2c 1987 LAND COVER

North Lower Puget Sound Sub—basin

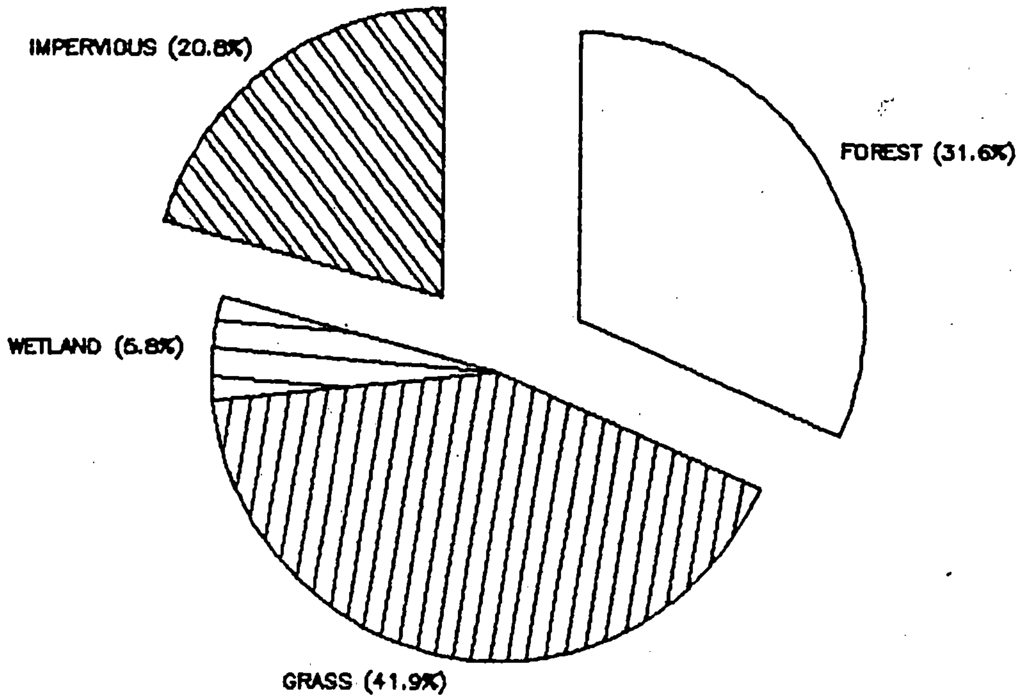


FIGURE 3.3.2d 1987 LAND COVER

Central Lower Puget Sound Sub—basin

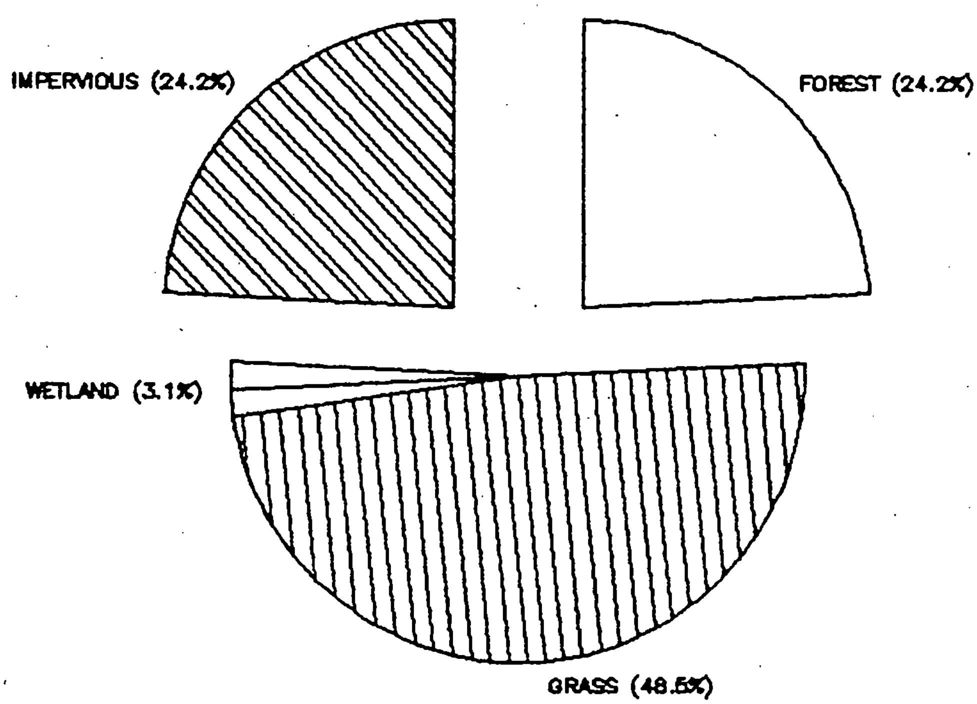
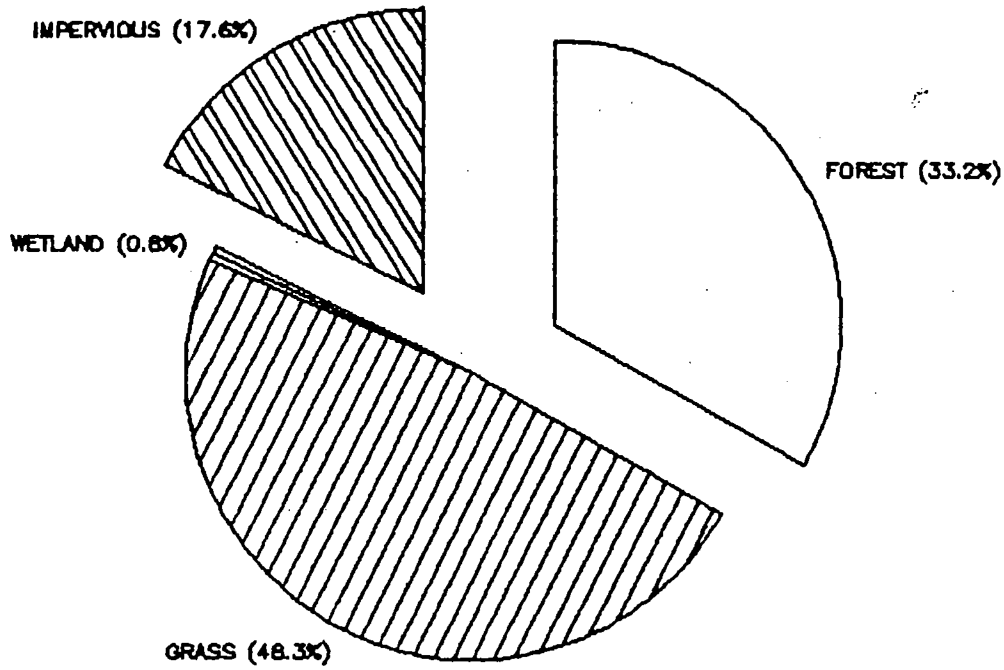


FIGURE 3.3.2e 1987 LAND COVER

South Lower Puget Sound Sub-basin



major stream are shown in Table 3.3.2. The lowest peak annual flow was found to be an outlier in the Log-Pearson analysis and tended to skew the regressions producing a poor fit (Figure 3.3.3). With this lowest point omitted (Figure 3.3.4), the regression was much better. Flow frequencies for the 1987 land use were computed without the lowest peak annual flow. Therefore the flow frequencies for the 1987 land use are based on 38 years of peak annual data.

Table 3.3.2

MODELED FLOW FREQUENCIES AT STREAM OUTLETS
UNDER 1987 LAND USE

BASIN	Peak Annual Flow Frequency (CFS) 2 year	10 year	25 year	100 year
West Hylebos	121	189	227	287
East Hylebos	119	193	231	290
McSorley Creek	107	153	173	199
Woodmont Creek	48	69	79	93
Redondo Creek	60	87	100	117
Cold Creek	38	54	61	70
Lakota Creek	58	81	92	106
Joes Creek	94	134	151	175

Peak Runoff Rates From Each Soil, Cover, and Slope Group - The relative influence of soil type, land cover, and slope is illustrated by the response of the various soil/cover/slope combinations modeled by the HSPF model for the planning area. Table 3.3.3 provides a summary of peak runoff rates, expressed in cubic feet per second per acre, for each pervious and impervious group used in the model. These discharge rates consisted of the sum of surface runoff, interflow, and groundwater.

Although peak runoff rates for the soil groups can be compared on a frequency basis, the actual storm contributing to the peak runoff rates may be different. In other words, the storm that generates the 2-year runoff rate for till soils is not necessarily the same storm that generates the 2-year runoff rate for outwash soils. Peak annual runoff rates for till soils occur from autumn through spring while the peak annual runoff rates from outwash occur exclusively during the winter or early spring. Till soils are more responsive to peak rainfall intensities, regardless of the time of year. Conversely, peak annual runoff rates for outwash soils (especially forested outwash) are affected by groundwater response, thus there is a tendency for the peak rate to occur during periods when the groundwater table is high.

Figure 3.3.3

SUBCATCHMENT H2, HYLEBOS CREEK,
1987 LAND USE, WITH OUTLIER POINT

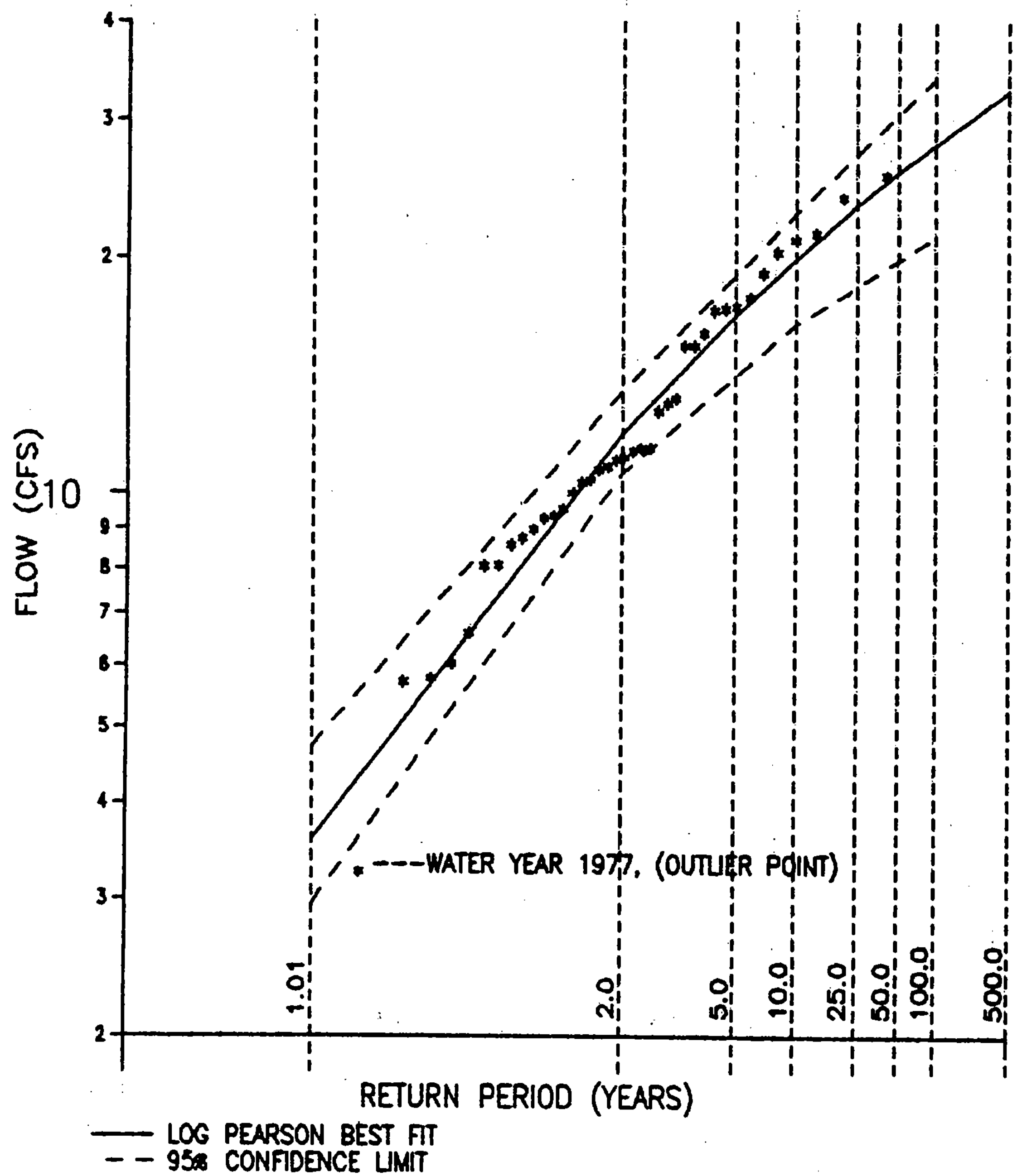


Figure 3.3.4

SUBCATCHMENT H2, HYLEBOS CREEK,
1987 LAND USE, WITHOUT OUTLIER POINT

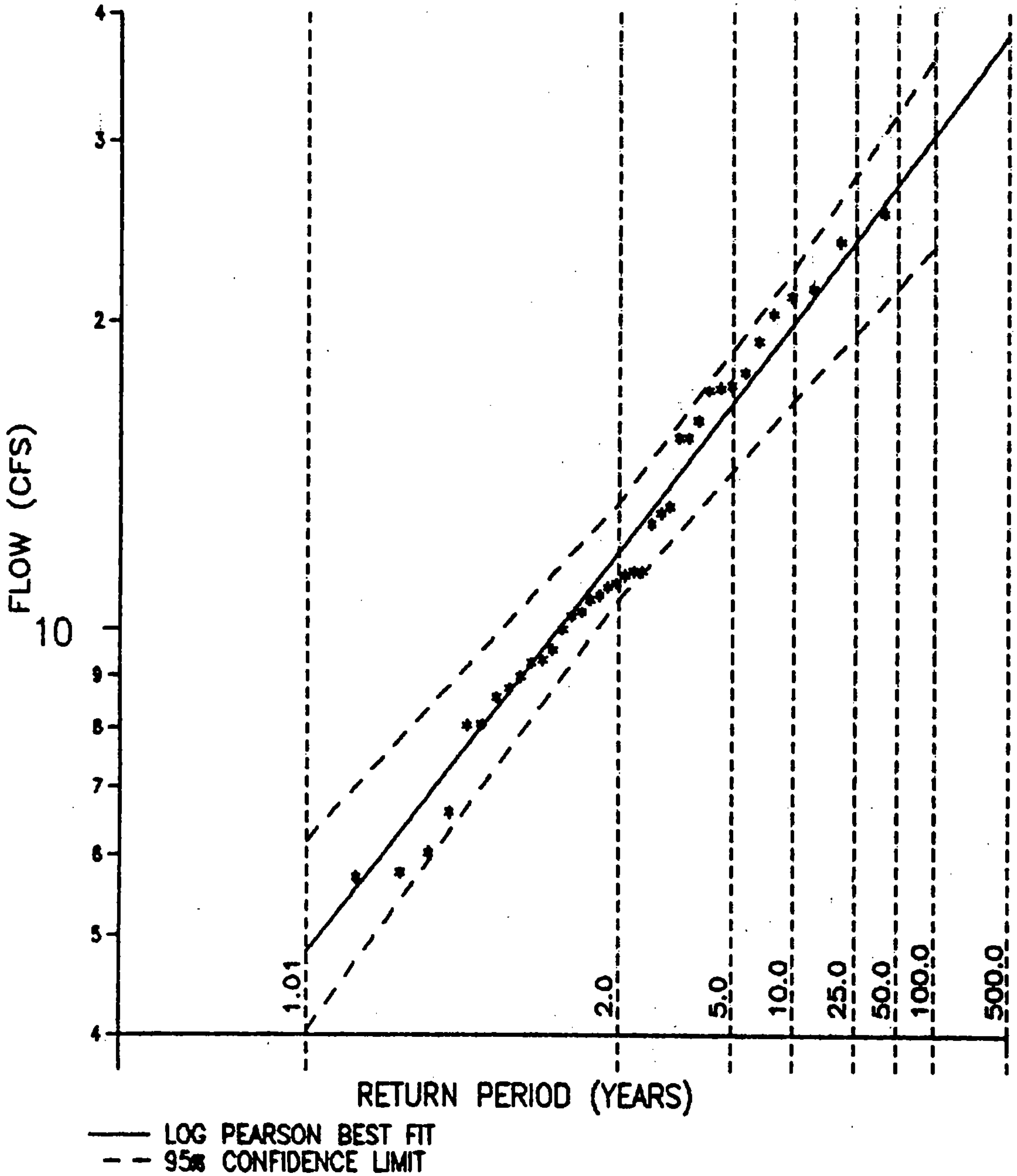


Table 3.3.3

PEAK FLOW RUNOFF RATES FROM EACH SOIL-COVER-SLOPE GROUP

Segment	Peak Annual Runoff Frequency (cfs/acre) 2-Yr	10-Yr	25-Yr	100-Yr
IMPERVIOUS	0.3489	0.5122	0.6050	0.7623
TILL GRASS FLAT	0.1984	0.2960	0.3352	0.3844
TILL GRASS STEEP	0.1597	0.2561	0.2985	0.3549
TILL GRASS MODERATE	0.1113	0.1936	0.2335	0.2912
TILL FOREST FLAT	0.0557	0.1154	0.1537	0.2222
TILL FOREST STEEP	0.0468	0.0706	0.0811	0.0956
TILL FOREST MODERATE	0.0314	0.0496	0.0585	0.0714
OUTWASH GRASS	0.0227	0.0645	0.0863	0.1174
OUTWASH FOREST	0.0010	0.0030	0.0055	0.0140
WETLAND	0.0390	0.1057	0.1456	0.2089

Unit Area Discharge Rates - Unit-area discharges (peak flow rate divided by upstream subcatchment area) were examined to identify areas that generate uncharacteristically high (or low) runoff rates and determine the hydrologic factors influencing these rates.

Unit-area discharges are influenced by land cover, slope, soil type, and stream reach volume. Land cover, slope, and soil type control the volume and rate of flow entering a stream reach, while the volume of the stream reach controls the amount of peak flow attenuation as the flows travel down the basin.

In general, stream reaches exhibiting the highest unit-area discharges have tributary areas with: 1) relatively high impervious areas, 2) relatively low coverage by forests, 3) predominantly till soils, and/or 4) few lakes and wetlands to attenuate flows.

Unit-area discharges at the outlet of each major basin are listed in Table 3.3.4. The Hylebos Creek basin has lower unit runoff rates than the Lower Puget Sound basin tributaries with the exception of Lakota Creek. The Hylebos Creek basin generates lower peak flows per acre because: 1) the level of urbanization is generally less, 2) there are more lakes and riparian wetlands that attenuate flow, and 3) the channel gradients are typically less than in the Lower Puget Sound basin. The Lakota Creek tributary generates less peak flow per acre because the majority of the runoff from 45 percent of the basin area infiltrates into Fisher Bog and does not contribute to downstream peak flow runoff.

Table 3.3.4

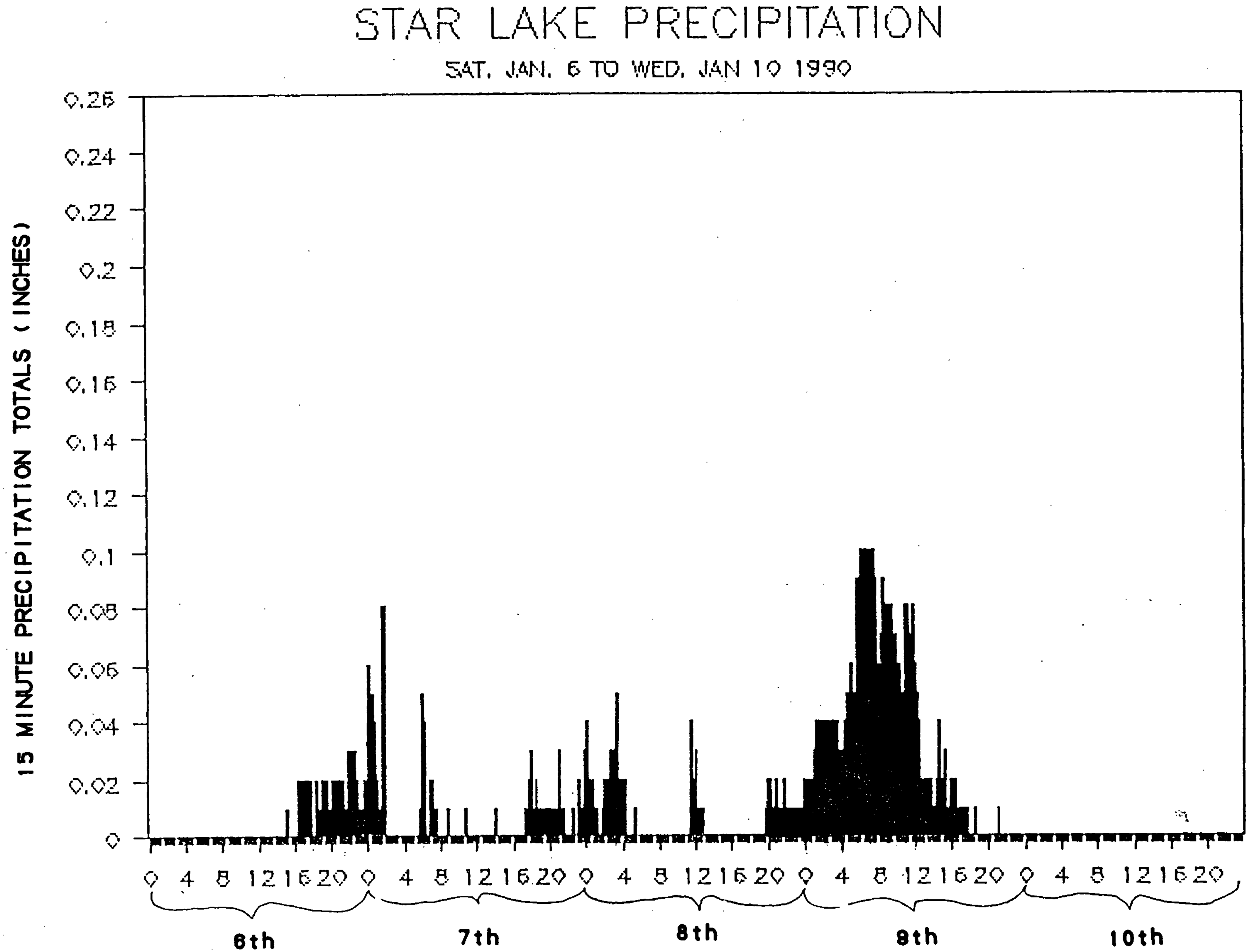
SUMMARY OF (1987) UNIT AREA DISCHARGE RATES
TRIBUTARY TO EACH BASIN OUTLET

BASIN	DISCHARGE PER UNIT ACRE (CFS/ACRE)
Joes Creek	0.073
Lakota Creek	0.049
Redondo Creek	0.131
Cold Creek	0.130
McSorley Creek	0.082
Woodmont Creek	0.216
East Hylebos	0.056
West Hylebos	0.043

Runoff Analysis From The January 9, 1990 Storm - During the analysis of the Hylebos and Lower Puget basins, a large storm event occurred on January 9, 1990 that produced considerable flooding, habitat, and erosion damage. This section describes the precipitation patterns leading up to the peak runoff, the antecedent conditions that contributed to the high runoff rate in the creeks, and a discussion of the simulated runoff flow frequencies on Hylebos Creek at the King-Pierce County line computed by the HSPF model.

Rainfall patterns were examined to determine the precipitation frequency of the storm event. Precipitation data from the Star Lake gage (Figure 3.3.5) were examined to determine the return period of the rainfall. Return periods were computed using a Log-Pearson analysis on the precipitation at the Sea Tac gage for the various durations and translated to the Star Lake gage using isopluvial maps (King County 1989). Return periods for the January storm with durations of 6 hours, 24 hours, and 96 hours at the Star Lake gage are shown in Table 3.3.5. The 24-hour period spanning January 8th to January 9th had a return period of 30 years and contained a 70-year six-hour duration. When the precipitation from the preceding three days are included, the 96-hour total is also about a 70-year event.

Figure 3.3.5



STAR LAKE PRECIPITATION
SAT. JAN. 6 TO WED. JAN 10 1990
15 MINUTE PRECIPITATION TOTALS (INCHES)
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20 0 4 8 12 16 20
6th
7th
8th
9th
10th

Table 3.3.5

RETURN PERIODS FOR THE JANUARY 1990 STORM
AT THE STAR LAKE PRECIPITATON GAGE

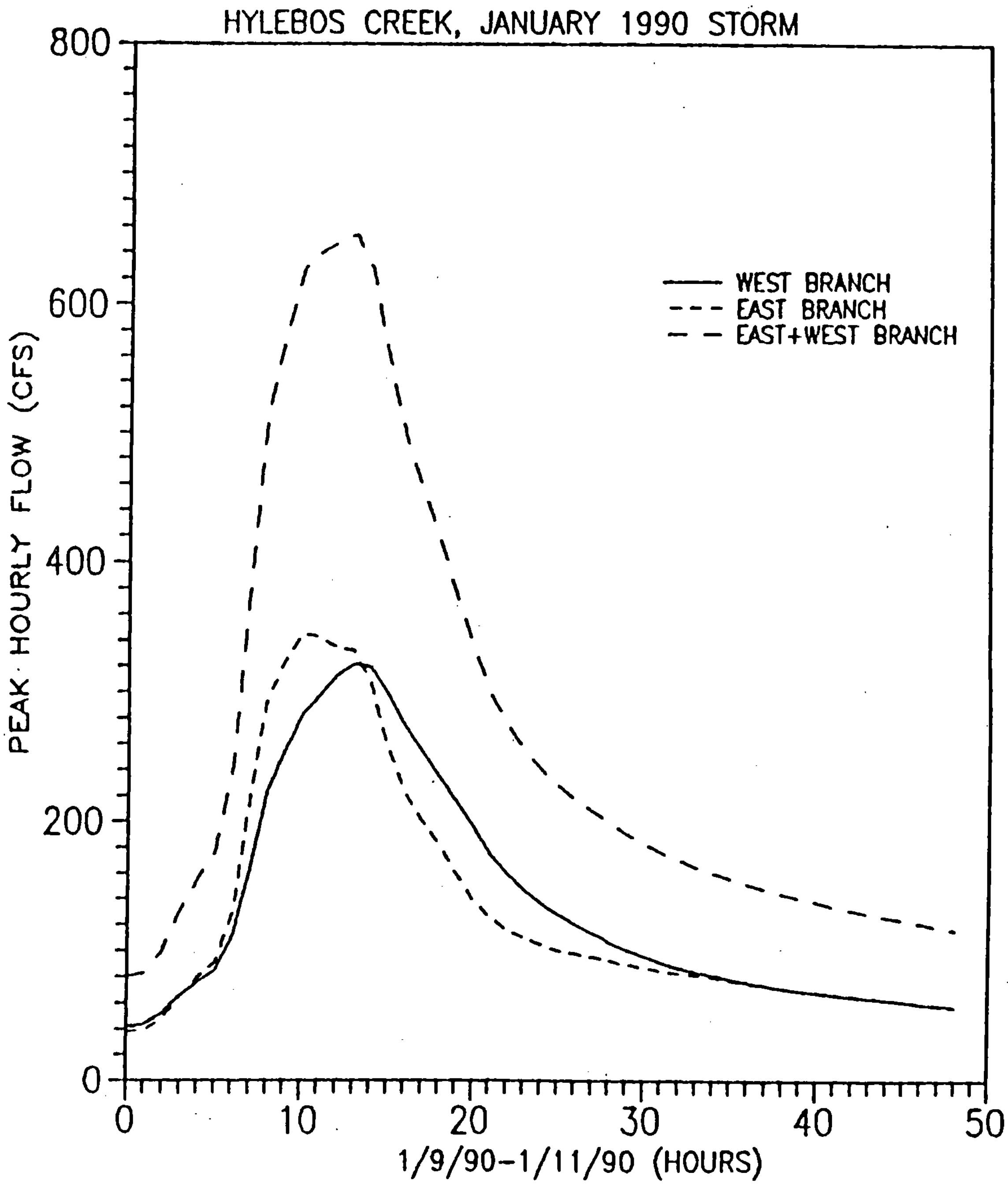
DURATION	MAX.PRECIP (INCHES)	RETURN PERIOD (YEARS)
1 HOUR	0.40	5
6 HOUR	1.89	70
24 HOUR	3.50	30
96 HOUR	5.96	70

Because of antecedent moisture in the soil column, lakes, wetlands, and surface depressions, the runoff flow frequency almost never equals the precipitation frequency. For example, had the January rainfall event occurred in September when the antecedent moisture is low, the resulting runoff event would have been much less significant than it actually was.

To determine the runoff return period of the January 1990 event, the precipitation record from the Star Lake gage was input to the HSPF model using 1987 land-use (the land-use that most closely represents 1990 conditions). Precipitation from the Sea Tac gage for the January storm was not available at the time of this analysis, so Star Lake was used instead. To accurately simulate the moisture conditions prior to the storm, the simulation period spanned October 1, 1989 through January 10, 1990. Flows were computed at the outlet of the East and West Branches and downstream of the confluence of East and West Branch Hylebos Creek (Figure 3.3.6).

Return periods were determined from the simulated 38-year series of peak annual flows plus the flow peak from the January 1990 storm, for a total of 39 years of peak flows. Simulated peak flows from the January 1990 storm were larger than any flows simulated in the previous 39-year series. A Log-Pearson distribution downstream of the confluence of the East and West Branches is shown in Figure 3.3.7. The January 1990 storm is the highest flow peak on the graph and lies just outside the 95 percent confidence interval. Table 3.3.6 lists the simulated magnitude of the January storm and the 50-and 100-year flows at the three locations based on similar Log-Pearson analyses. The runoff event produced by the January 1990 storm therefore had a return period greater than 50 years but less than 100 years, based on 1987 land-use conditions.

Figure 3.3.6



HYLEBOS CREEK, JANUARY 1990 STORM
800
600
400
200
0
PEAK HOURLY FLOW (CFS)
0
10
20
30
40
50
1/9/90–1/11/90 (HOURS)
WEST BRANCH
EAST BRANCH
EAST+WEST BRANCH

Figure 3.3.7

EAST+WEST BRANCH HYLEBOS CREEK
EXISTING LAND USE WITH JANUARY 1990 STORM

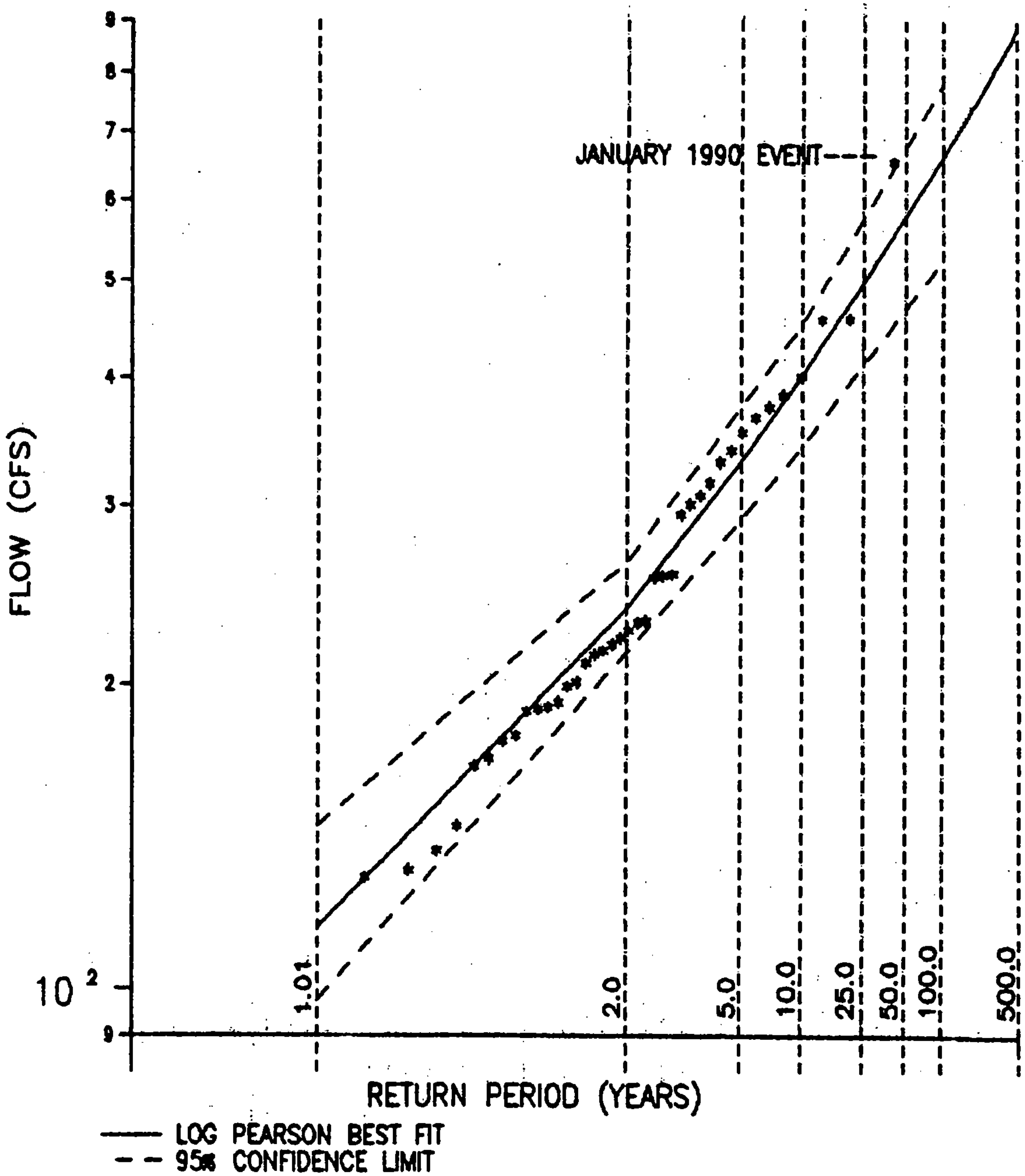


Table 3.3.6

MAGNITUDE AND RETURN PERIOD OF JANUARY 1990 STORM AT THE OUTLET OF THE HYLEBOS CREEK BASIN

BASIN	FLOW (CFS) 50 YEAR	100 YEAR	JAN 9, 1990 STORM
WEST BRANCH	293	337	322
EAST BRANCH	303	348	345
EAST+WEST BRANCH	579	663	654

Mean Annual Flow Under 1987 Land Use - Mean annual flow is used to determine whether a project is subject to U. S. Army Corps of Engineers individual permit requirements regarding filling of wetlands (flows greater than 5 cfs), or is considered a "Shoreline of the State" (flows greater than 20 cfs). Currently mean annual flows are determined by gaging records that often span short periods of time or do not represent current land-use conditions. The flows computed by the HSPF model provide a more complete record of flows and produces them at interior locations within the basin. Figures 3.3.8a-f list mean annual flows for the major creeks in the Hylebos and Lower Puget Sound basins. The values on these figures represent the mean annual flow. No shorelines of the State are located in freshwater bodies of these basins and only the lowest subcatchments of the West Branch of Hylebos Creek (WH1 and WH2) are above the 5 cfs Corps of Engineers threshold. These values are based on 39 years of 15 minute simulated flows under 1987 land-use.

Future Conditions

Sources of Future Land-Use Data - Land use for the future model scenario was derived by taking the most dense land use from: 1) existing land use, 2) existing zoning, 3) the King County Comprehensive Plan, and 4) the 1986 King County Federal Way Community Plan and Area Zoning. Regulations governing land use have changed with the incorporation of the City of Federal Way. However, only minor differences exist between the recently adopted 1990 City of Federal Way Comprehensive Land Use Plan and the land-use map used for future modeling. The differences that do exist should only affect flows on a subcatchment level; the cumulative difference at the outlet of the basins should be negligible. Subcatchments where the new land use will produce flows significantly different from the flows predicted in this analysis are listed below.

1. Business Corridor Expansion Between SR 99 and I-5 (subcatchments WH10 and H9). The 1990 Federal Way Plan changed zoning from multifamily to business/office and these areas are expected to produce flows higher than predicted in this analysis. This flow increase should be significant downstream to subcatchment WH4 on West Branch Hylebos Creek and downstream to H6 on East Branch Hylebos Creek.

Figure 3.3.8a

West Branch Hylebos Creek

SIMULATED MEAN ANNUAL FLOW

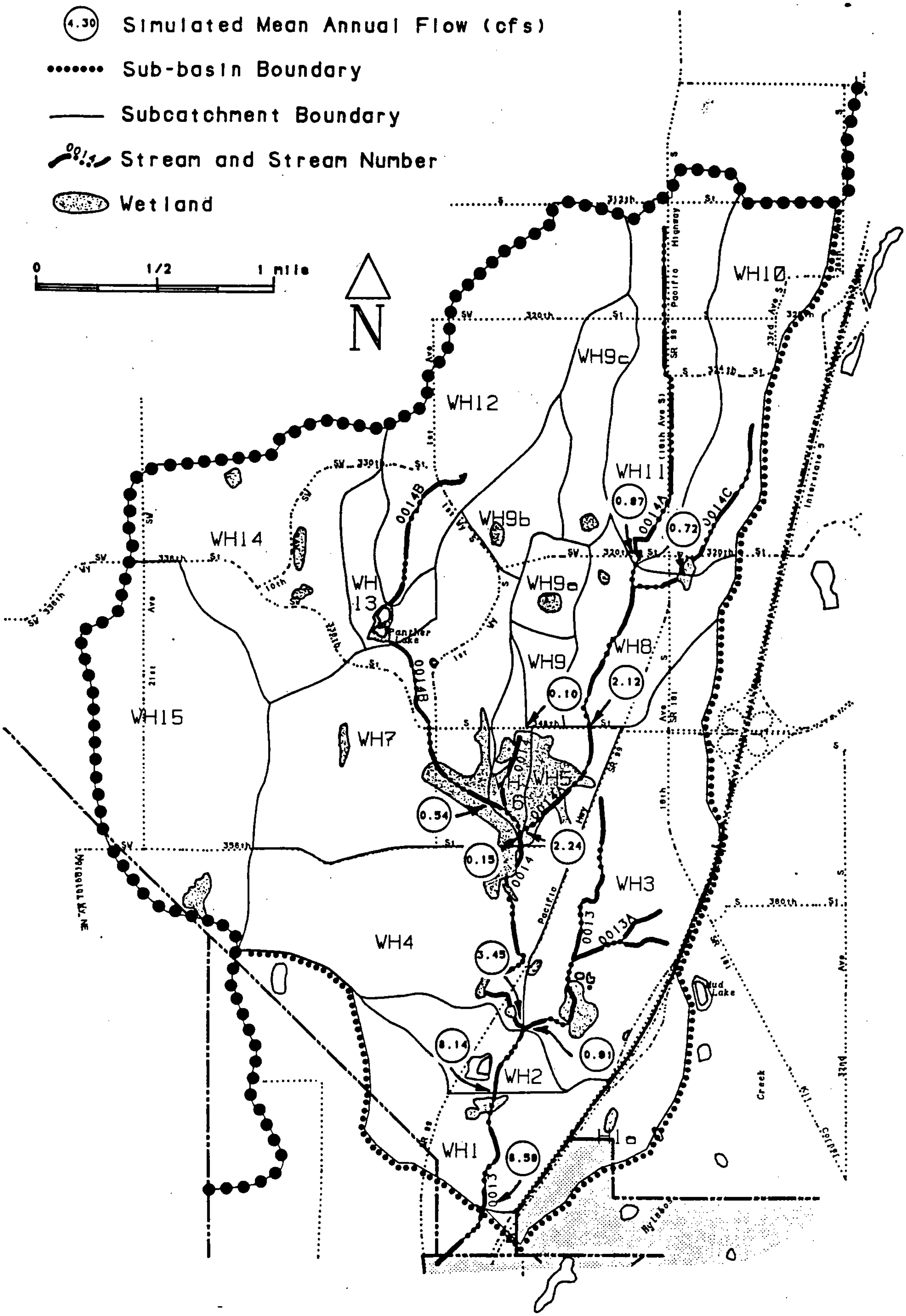


Figure 3.3.8b

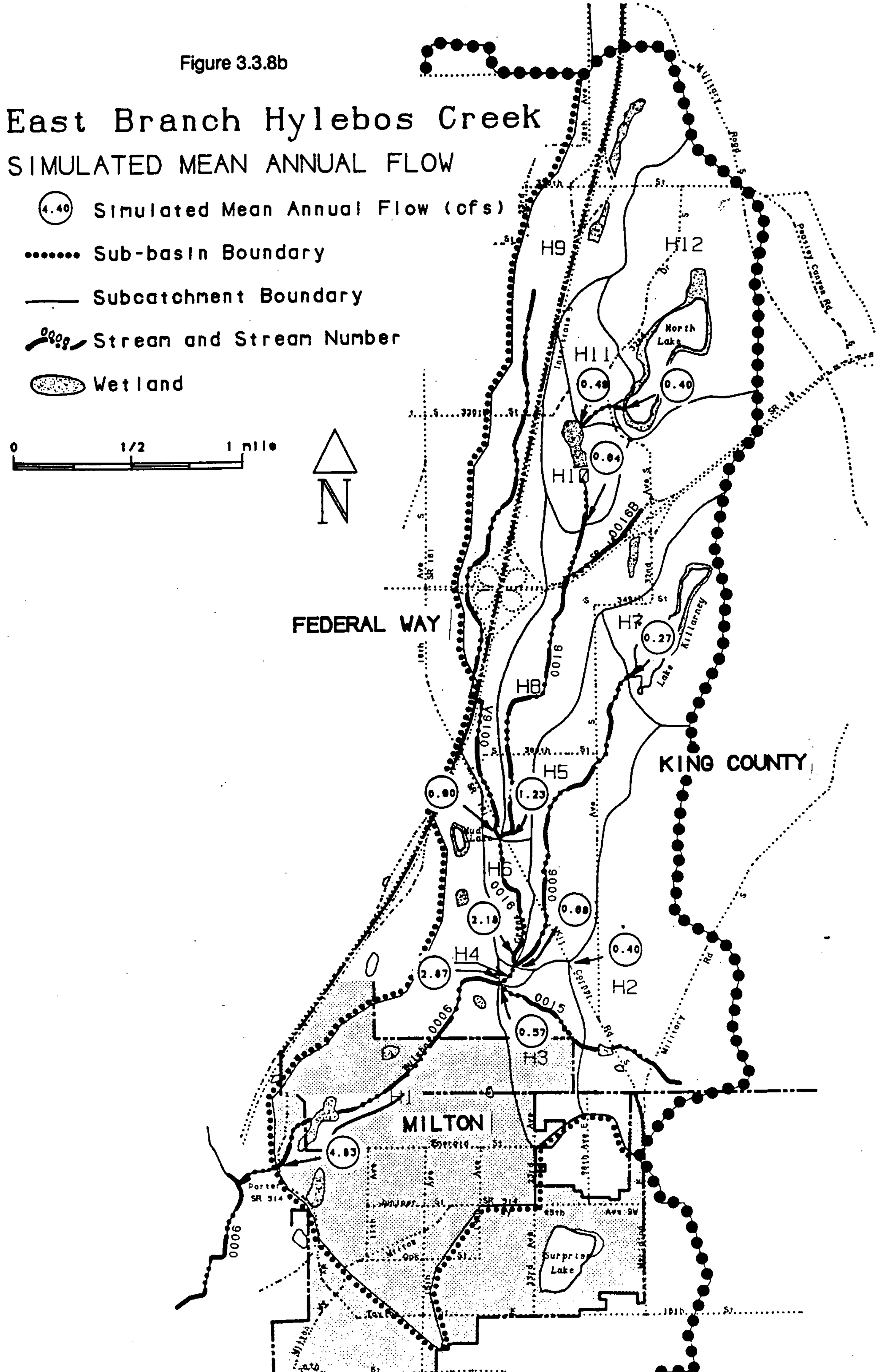

East Branch Hylebos Creek
SIMULATED MEAN ANNUAL FLOW
4.40 Simulated Mean Annual Flow (cfs)
Sub-basin Boundary
Subcatchment Boundary
Stream and Stream Number
Wetland
0
1/2
1 mile
N
H9
H12
H11
North Lake
0.48
0.40
H10
0.84
0016B
FEDERAL WAY
H7
0.27
Lake Killarney
0018
H8
0016A
H5
0.80
1.23
KING COUNTY
Mud Lake
H6
0016
0006
2.18
0.88
0.40
H4
2.87
H2
0015
0.57
H3
0006
H1
MILTON
4.83
Porter
SR 514
Surprise Lake
0006

Figure 3.3.8c

Lower Hylebos Creek

SIMULATED MEAN ANNUAL FLOW

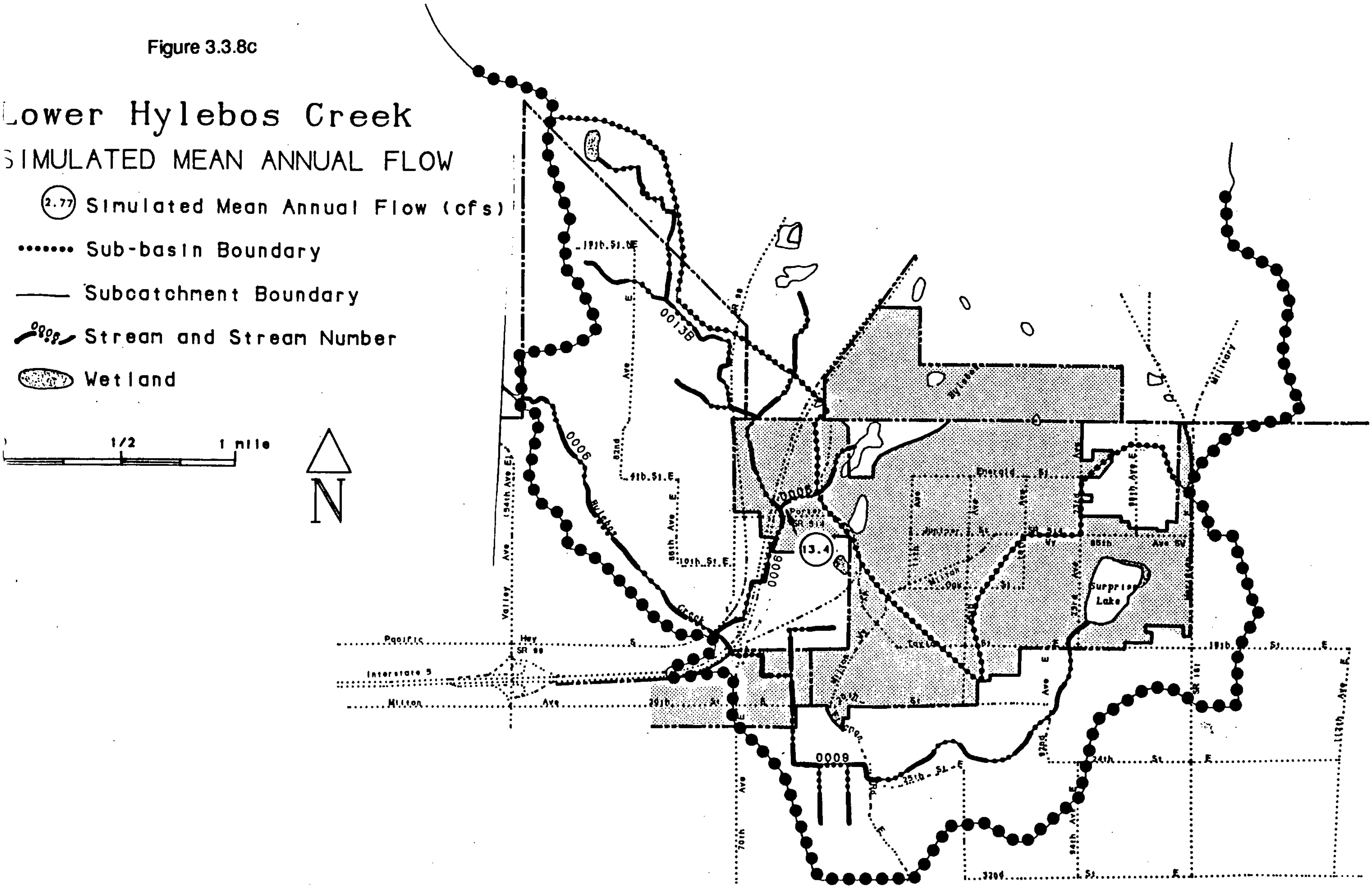


Figure 3.3.8d

North Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW

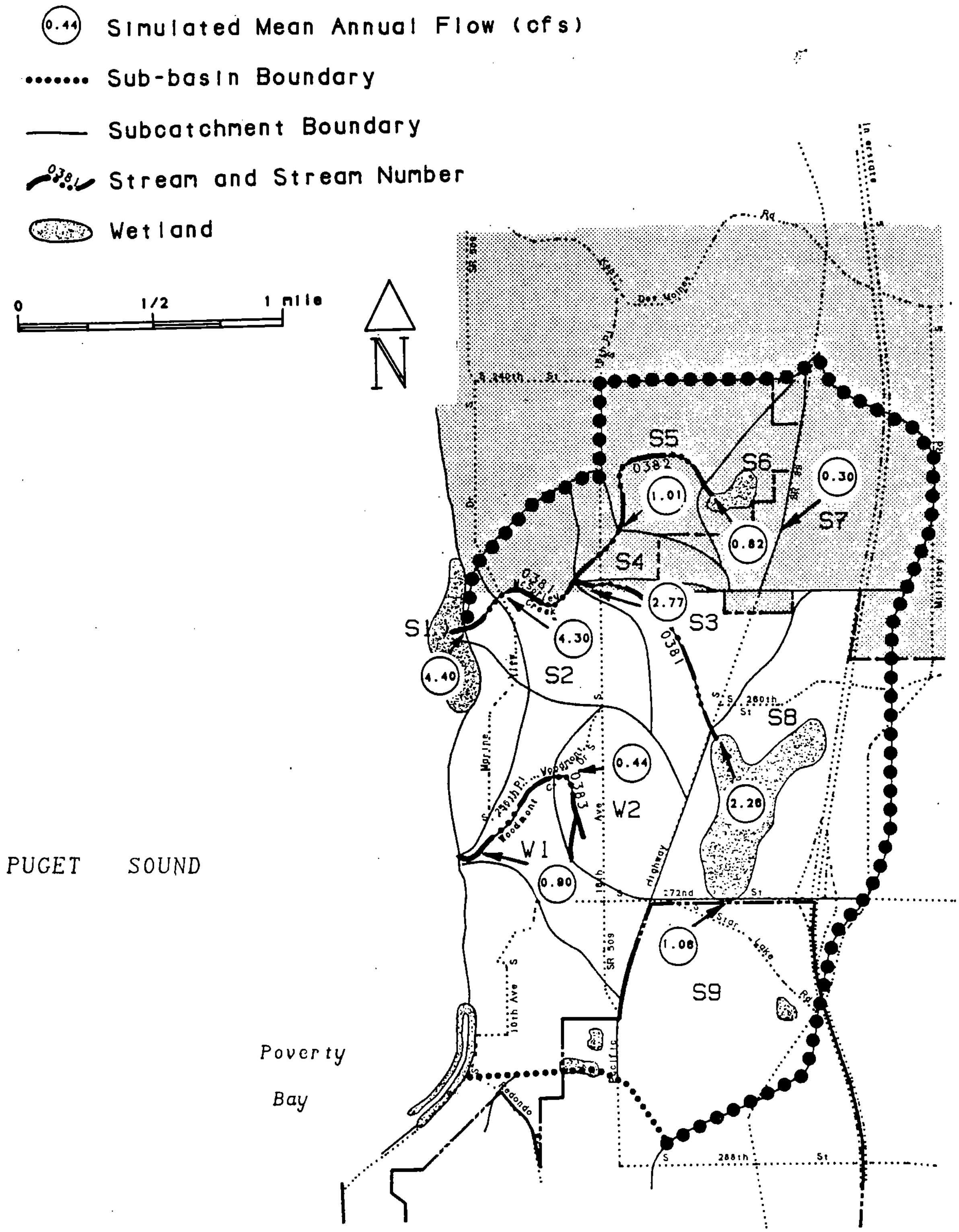
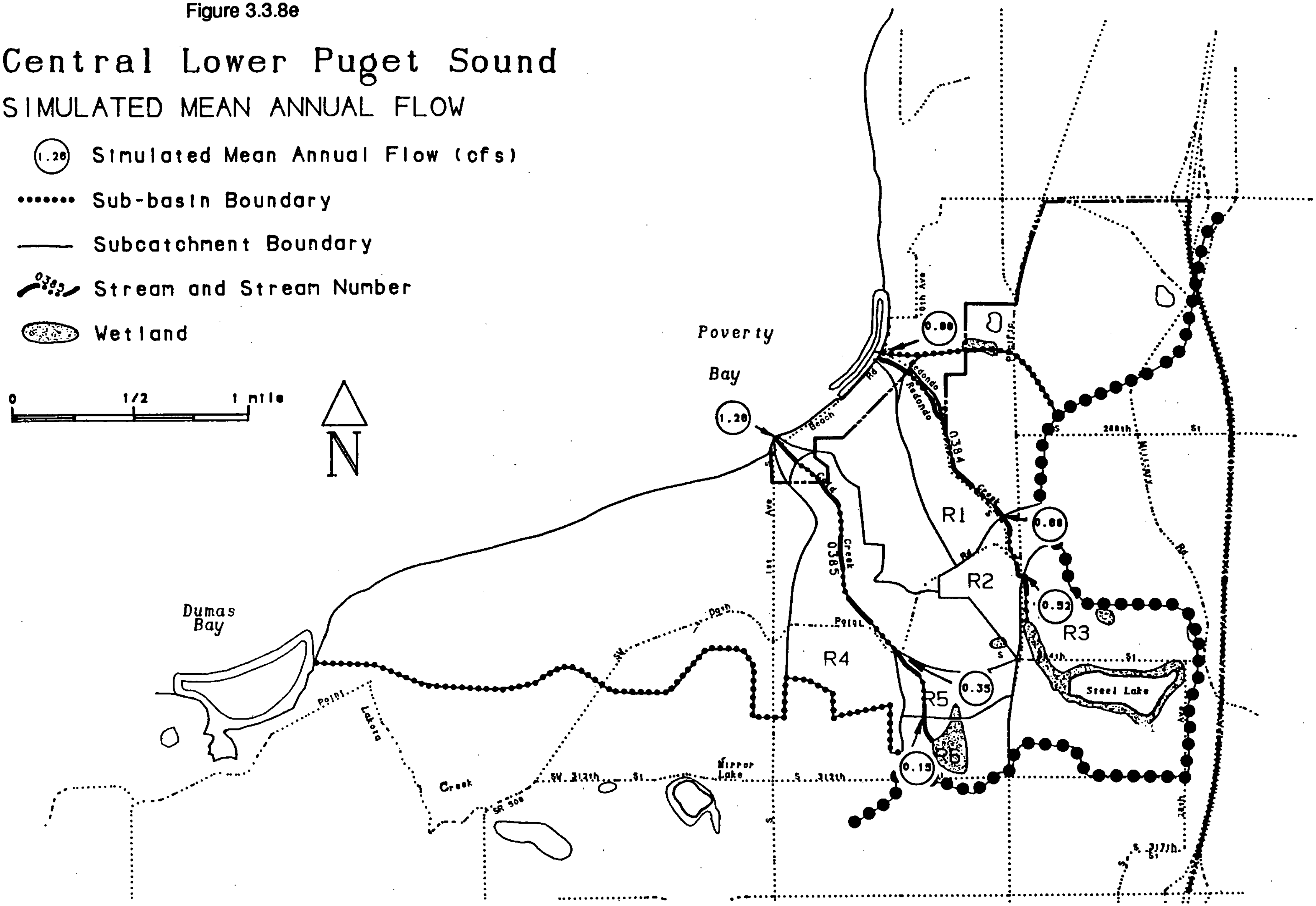


Figure 3.3.8e

Central Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW



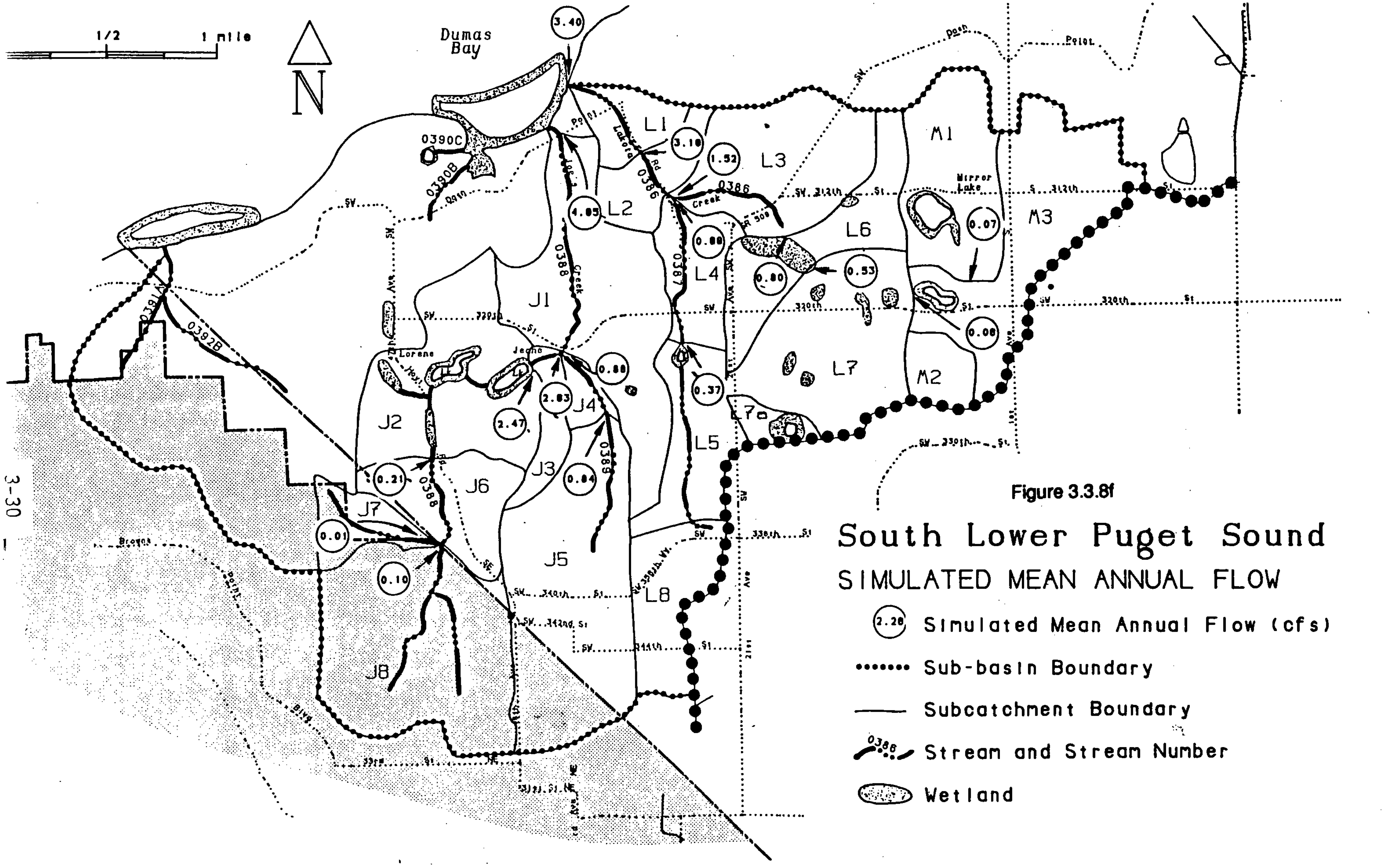


Figure 3.3.8f

South Lower Puget Sound

SIMULATED MEAN ANNUAL FLOW

2. **Open Space Surrounding Panther Lake (subcatchments WH7, WH12 and WH13).** Zoning surrounding Panther Lake was changed from high-density residential to open space. Flows from these areas will be less than simulated in the future land use analysis; however, since the changed area represents a small percentage of the total catchment area, the difference in runoff should be small.

3. **Downzone in the Lower West Branch Hylebos Creek (subcatchments WH1 and WH2).** Zoning in subcatchments WH1 and WH2 was converted from low-density single-family residential to rural land uses. The actual flows from these sub-catchments will be lower than the simulated flows. But again, since these areas represent a small percentage of the total area discharging to the lower reaches, the difference in runoff between the new Community Plan and the modeled land-use should be small.

Differences Between Future and Existing Land Use - Under build-out conditions approximately 94 percent of the Hylebos Creek basin will be developed at urban densities (Figures 3.3.9a and b). The West Branch Hylebos Creek tributary area will continue to be composed primarily of commercial and residential land uses, but the amount of commercial area will nearly double over 1987 land use. The East Branch Hylebos tributary area will continue to be dominated by single-family residential; however, multifamily developments will increase by a factor of ten over 1987 land use and single family residential development will increase by a factor of 2.5 (Table 3.3.7).

Table 3.3.7

SUMMARY OF FUTURE LAND USES TRIBUTARY TO EACH BASIN OUTLET

	FUTURE LAND USE (ACRES)				
BASIN	COMM.	MULTI-FAMILY	3-7 UNITS/AC	1-3 UNITS/AC	RURAL
West Hylebos	1516.5	921.3	1495.4	781.3	28.6
East Hylebos	499.1	917.5	1959.0	103.3	64.4
McSorley Creek	433.3	194.3	922.5	0.0	34.4
Woodmont Creek	74.8	2.3	195.0	12.9	36.3
Redondo Creek	101.9	88.0	366.1	0.0	36.7
Cold Creek	89.6	36.7	229.4	2.8	34.6
Lakota Creek	168.5	265.9	1188.8	101.6	64.4
Joes Creek	88.7	9.4	1411.4	22.7	46.8

In the Lower Puget Sound basin, over 90 percent of the land area is developed under the future land-use condition (Figures 3.3.9c-e). Increases in land-use density are not as dramatic as in the Hylebos Creek basin because the Lower Puget Sound area has already approached build-out under 1987 conditions. There is, however, a significant potential for conversions of developed areas to higher density uses. For example, under the future land-use scenario, multi-

FIGURE 3.3.9a FUTURE LAND USE

West Branch Hylebos Creek Sub-basin

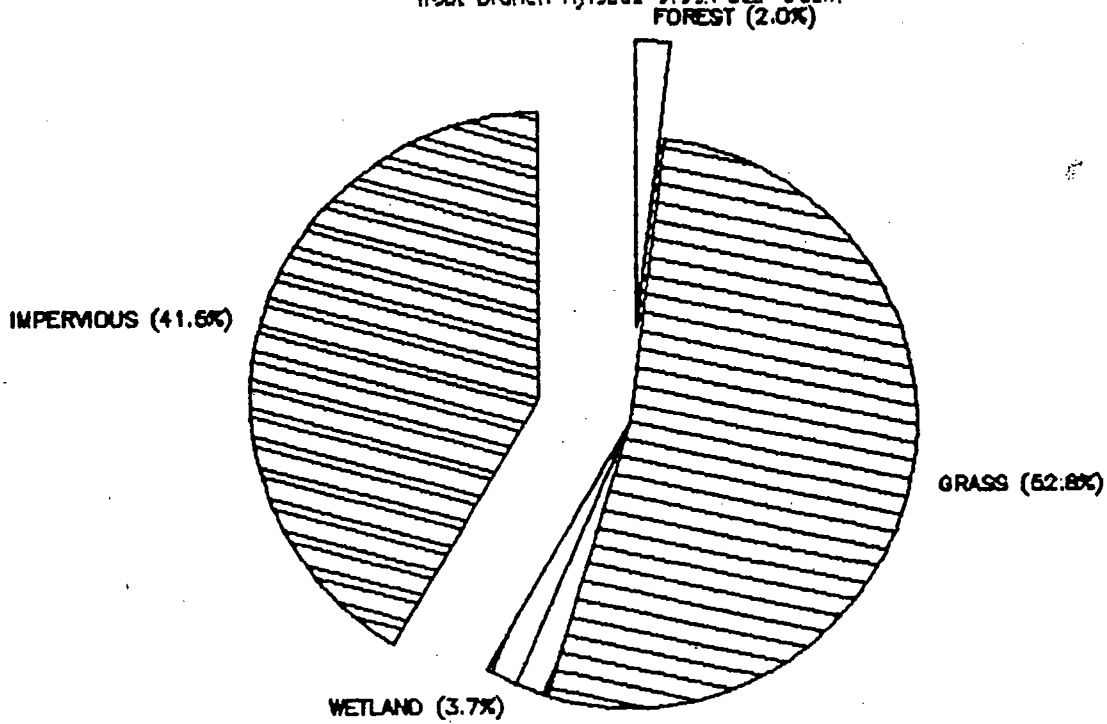


FIGURE 3.3.9b FUTURE LAND USE

East Branch Hylebos Creek Sub-basin

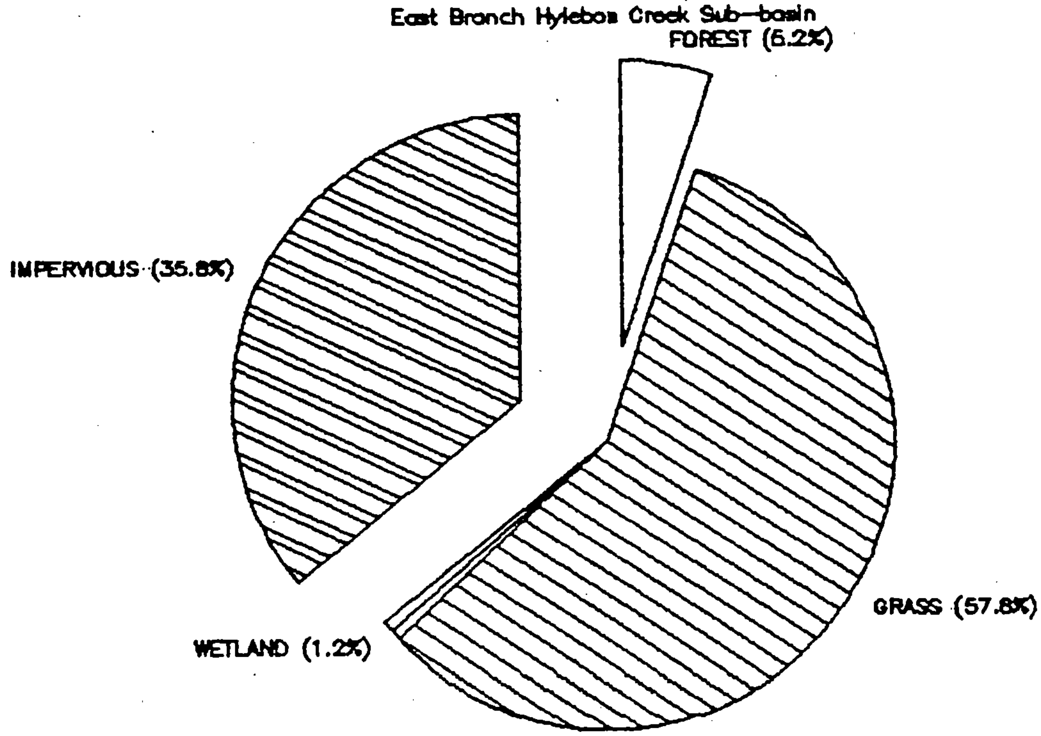


FIGURE 3.3.9c FUTURE LAND USE

North Lower Puget Sound Sub-Basin

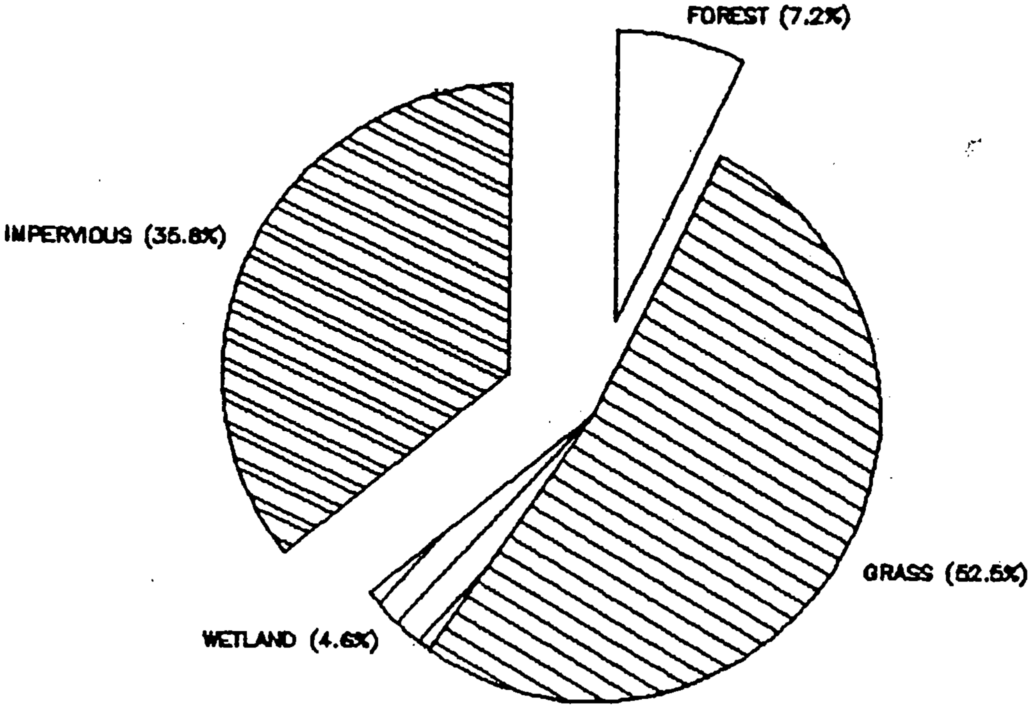


FIGURE 3.3.9d FUTURE LAND USE

Central Lower Puget Sound Sub-Basin

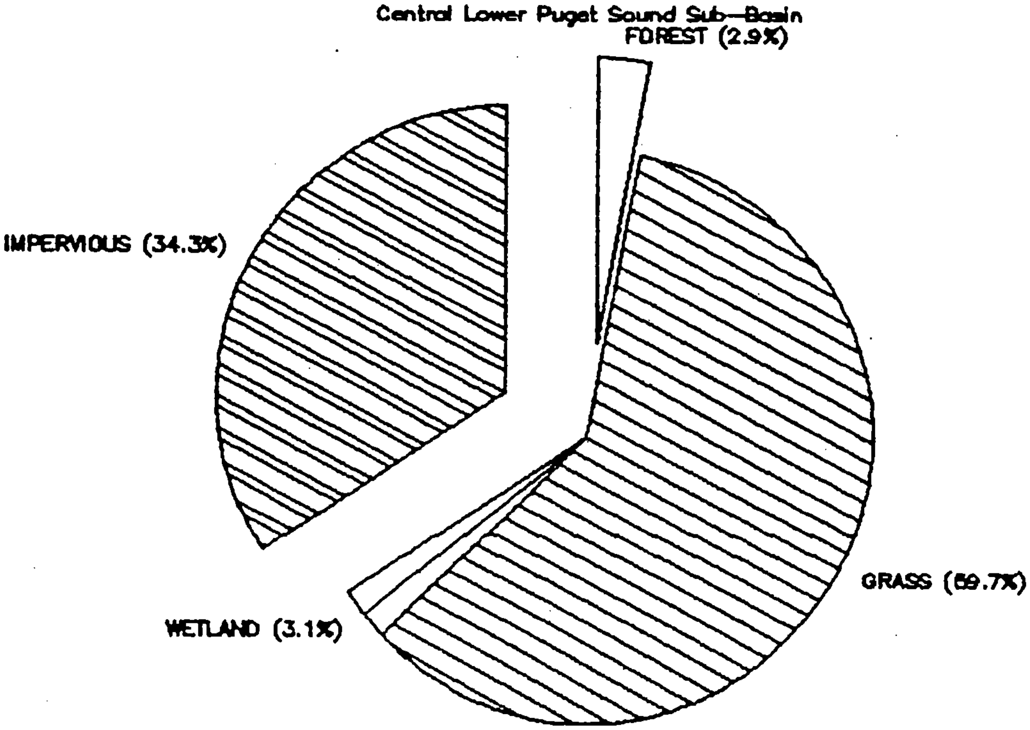
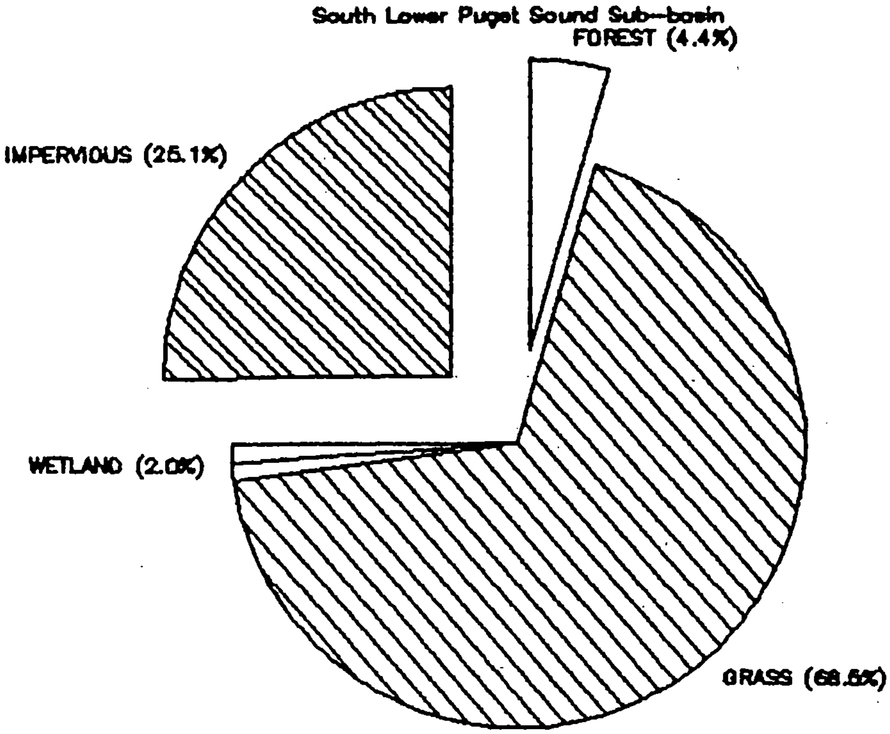


FIGURE 3.3.9e FUTURE LAND USE



family areas in the Joes Creek drainage decreases while commercial land use nearly doubles over the 1987 land-use scenario. Commercial land use throughout the Lower Puget Sound basin nearly doubles over 1987 land use.

As the basins proceed to build-out, there is a potential overall loss of 5,620 acres of forested land (91% of the 1987 total) and 272 acres of wetlands (37% of the 1987 total). The loss of wetlands is the result of development in areas that function hydrologically as wetlands but are currently not inventoried. One of the most significant areas of uninventoried wetlands is along the north fork of Hylebos Creek (tributary 0013). The tributary area (subcatchment WH3) contains 123 acres of wetlands. These wetlands provide significant groundwater discharge to the creek augmenting flows during dry periods. All but 19 acres of the wetlands in this subcatchment are not inventoried and can potentially be developed.

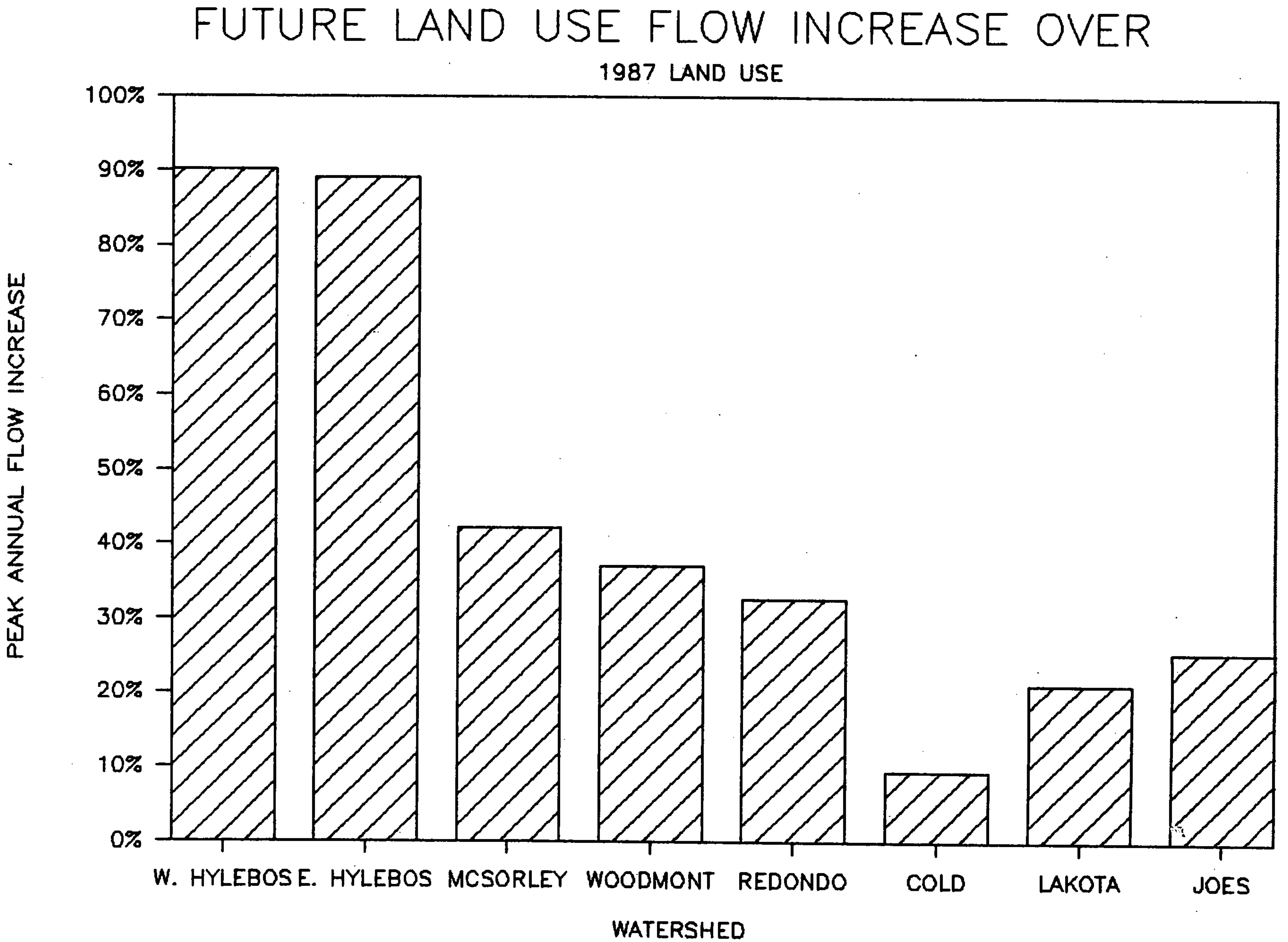
Peak Flow Rates Under Future Land Use - The future land-use scenario was based on an unmitigated condition. This assumed no onsite or regional detention for any part of the basin. This unmitigated assumption together with the land-use assumptions detailed in the previous section, produced a "worst case" future scenario. Unless the land-use plans used to derive the future land-use condition are altered, future flows will not exceed the flows produced by this future land-use scenario. Various flow mitigation techniques will be discussed in the solutions section of the Hylebos Creek and Lower Puget Sound Basin Plan.

Peak annual flow data for each reach were analyzed using a Log-Pearson analysis according to the guidelines presented by the WRC (Bulletin 17a, 1977). Flows were determined for the 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flows. The lowest ranked peak annual flow, which was an outlier point in the Log-Pearson distributions under 1987 land use, was typically well within the 95 percent confidence interval under the future land use scenario. Therefore the full 39-year record of peak annual flows were used to compute flow frequencies for this scenario.

A listing of the predicted 2-, 10-, 25-, and 100-year flows are presented in Table 3.3.8 for the future land-use scenario at the outlet of each stream system Figure 3.3.10 shows the magnitude of peak flow increases between the 1987 and future land-use scenarios for each of the modeled creek systems in the basins. These percentage increases are based on the average of the predicted increases for the 2-, 5-, 10-, 25-, 50-, and 100-year flows.

Peak flows at the basin outlets increase from 10 percent to 90 percent. Flow increases ranging up to eight-fold were computed at some interior subcatchment points (see Chapter 4, Sub-basin Conditions, for a detailed discussion of these areas). The Hylebos Creek tributaries are predicted to have a much higher increase in peak flow than the Lower Puget Sound tributaries, a reflection of the lower state of development and the higher intensity land-use zoned in the Hylebos Creek basin.

Figure 3.3.10



FUTURE LAND USE FLOW INCREASE OVER
1987 LAND USE
PEAK ANNUAL FLOW INCREASE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Table 3.3.8

MODELED FLOW FREQUENCIES AT STREAM OUTLETS
UNDER FUTURE LAND USE

BASIN	Peak Annual Flow Frequency (CFS) 2 year	10 year	25 year	100 year
West Hylebos	235	363	431	538
East Hylebos	259	375	430	511
McSorley Creek	163	220	243	273
Woodmont Creek	67	95	108	125
Redondo Creek	80	116	132	156
Cold Creek	41	59	67	76
Lakota Creek	71	98	110	128
Joes Creek	115	167	190	222

Forested Land Use

Land Cover - The Hylebos Creek and Lower Puget Sound basins represent one of the most heavily developed areas relative to unincorporated areas in King County. Mitigating existing as well as potential problems identified by the future land-use modeling runs may require reducing flows well below the current (1987) land-use flow level. For example, solving instream erosion problems may require reducing flows to a point where stream channels are stable. Since many of the stream channels in the Hylebos Creek and Lower Puget Sound basins were formed by historic flows when the basin was forested, the stream channel will be stable only under a flow regime similar to what existed under forested land-use conditions. To establish the relative magnitude and examine the statistical characteristics of flows before development occurred in the basins, a model run was performed with all development densities replaced with forest cover.

Lack of data describing the physical characteristics of the basin in a pre-developed state necessitated making the following assumptions:

1. The channel cross-sections used in the model to route flows were not changed from either of the other land-use scenarios. This assumption is not expected to significantly alter predicted flows.

2. Culverts and other human-made hydraulic structures were assumed to be present. These structures often act as restrictions during high flow events and provide detention, thus reducing flows. The amount of flow attenuated by this storage is small for most structures and will result in only small discrepancies in the peak flow rates.

3. The amount of wetlands in the system was assumed to be the same as the 1987 land use scenario, even though significant wetland areas have been lost with urbanization in the basins.

4. Tributaries diverted historically, such as 0016A, were left in their current (1987) state.

Peak Flows - Peak annual flow data for each reach were analyzed using a Log-Pearson analysis with flows computed for the 1.01-, 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flows. The lowest ranked peak annual flow was again an outlier in the Log-Pearson distributions under the forested land-use. This point was dropped in the Log-Pearson analysis, leaving 38 years of peak annual flows to compute flow frequencies. Log-Pearson plots of the peak annual flow data are shown in Figures 3.3.11a and b for selected basins.

Figure 3.3.12 shows the magnitude of peak flow increases between the 1987 land-use and the forested land-use scenarios for each of the modeled creek systems in the planning area. Percentage increases are based on the average of the predicted increases for the 2-, 5-, 10-, 25-, 50-, and 100-year flows.

Peak flow increases between forested and 1987 conditions range from 65 percent to over 300 percent at the basin outlets. Flow increases ranging up to 400 percent were computed at some interior subcatchment points (see Chapter 4 for a detailed discussion of these areas). Peak flows under 1987 land use from the Hylebos Creek sub-basins are between 65 percent and 85 percent higher than they were under the forested condition, with the highest flow increases located in the headwaters where the land use is dominated by commercial development. These increases are still much lower than the Lower Puget Sound drainages, which have 1987 peak flows that are between 120 percent and 300 percent higher than under forested conditions. The high flow increase in Lakota Creek (308% higher than under forested conditions) is attributable to the nearly built-out state of the basin under 1987 land use, and the high percentage of outwash soils in the basin. Conversion of forest cover to high-density residential developments on outwash soils resulted in particularly large flow increases.

The runoff computed from the future and forested land use scenarios represents the extremes of the flow regime in the Planning Area. Figure 3.3.13 shows flows under 1987 land use expressed as a percentage of change between forested and future land use. Zero on this graph represents a forested condition while 100 represents future build-out. For example, the Hylebos Creek Basin has experienced roughly 30 percent of its total possible flow increase, whereas Cold Creek has experienced over 85 percent of its total possible flow increase. Regulatory measures could therefore be effective at controlling flows in the Hylebos Creek Basin, while structural solutions would be more effective in the Cold Creek drainage.

Changes to Flow Durations

Increased urbanization will not only increase the magnitude of peak flows but also will increase their aggregate duration over the simulation period, and the number of flow events, but it will reduce the average length of time per event that flows exceed a given level.

Figures 3.3.14a and b show the difference in flow durations for the three land-use scenarios at the outlet of the Hylebos and Lakota Creek watersheds. In the Hylebos Creek basin, the amount of time the forested 2-year flow is exceeded under 1987 land use is over double what it is under forested conditions. The amount of time the forested 2-year flow is exceeded under future land use is over 10 times as long as under the forested condition. Therefore, in the long term, the flow representing the forested 2-year flow under future land use produces over 10 times the amount of instream erosion and transport as the same flow did under forested conditions.

Figure 3.3.11a

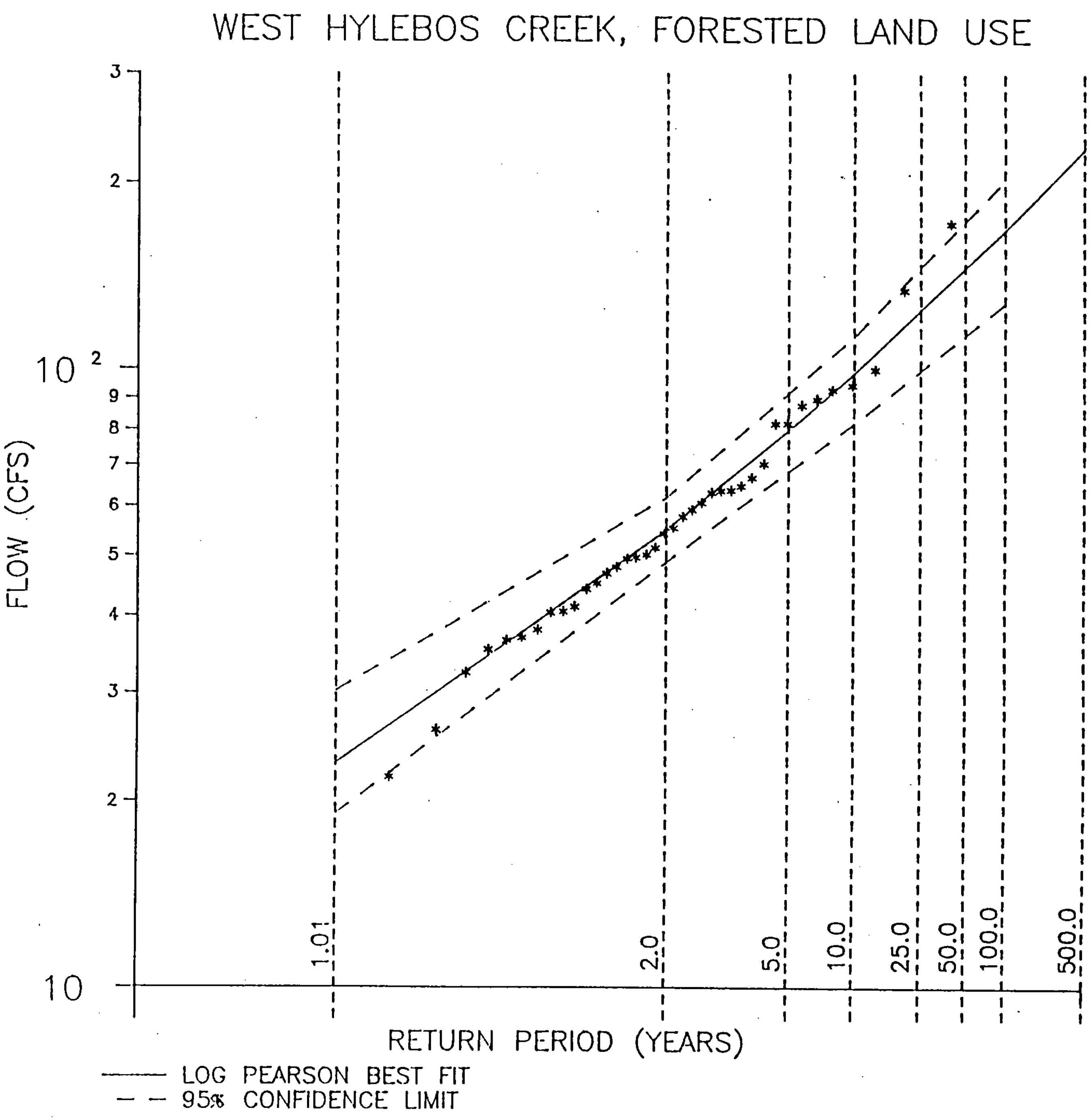


Figure 3.3.11b

LAKOTA CREEK, FORESTED LAND USE

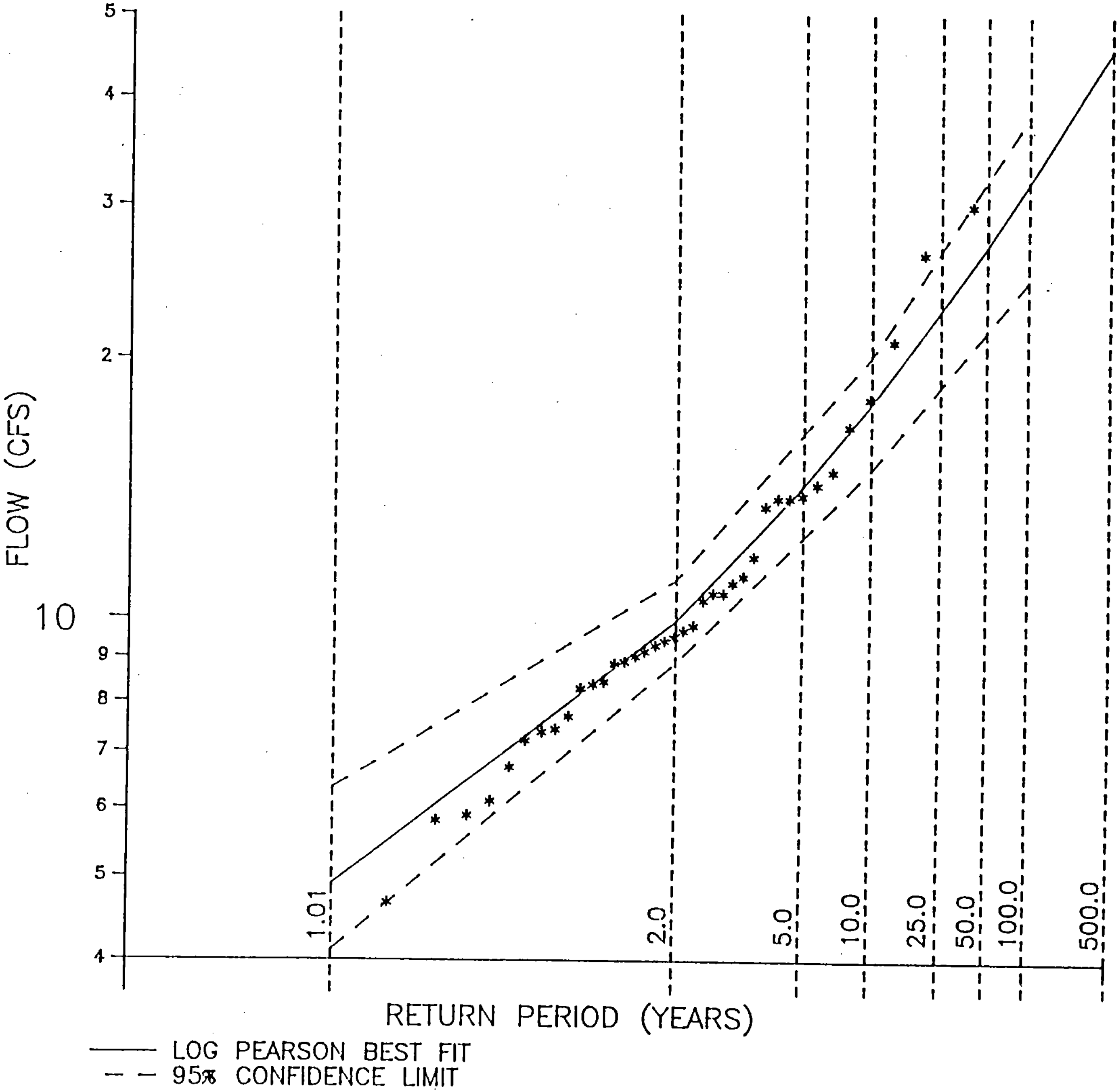
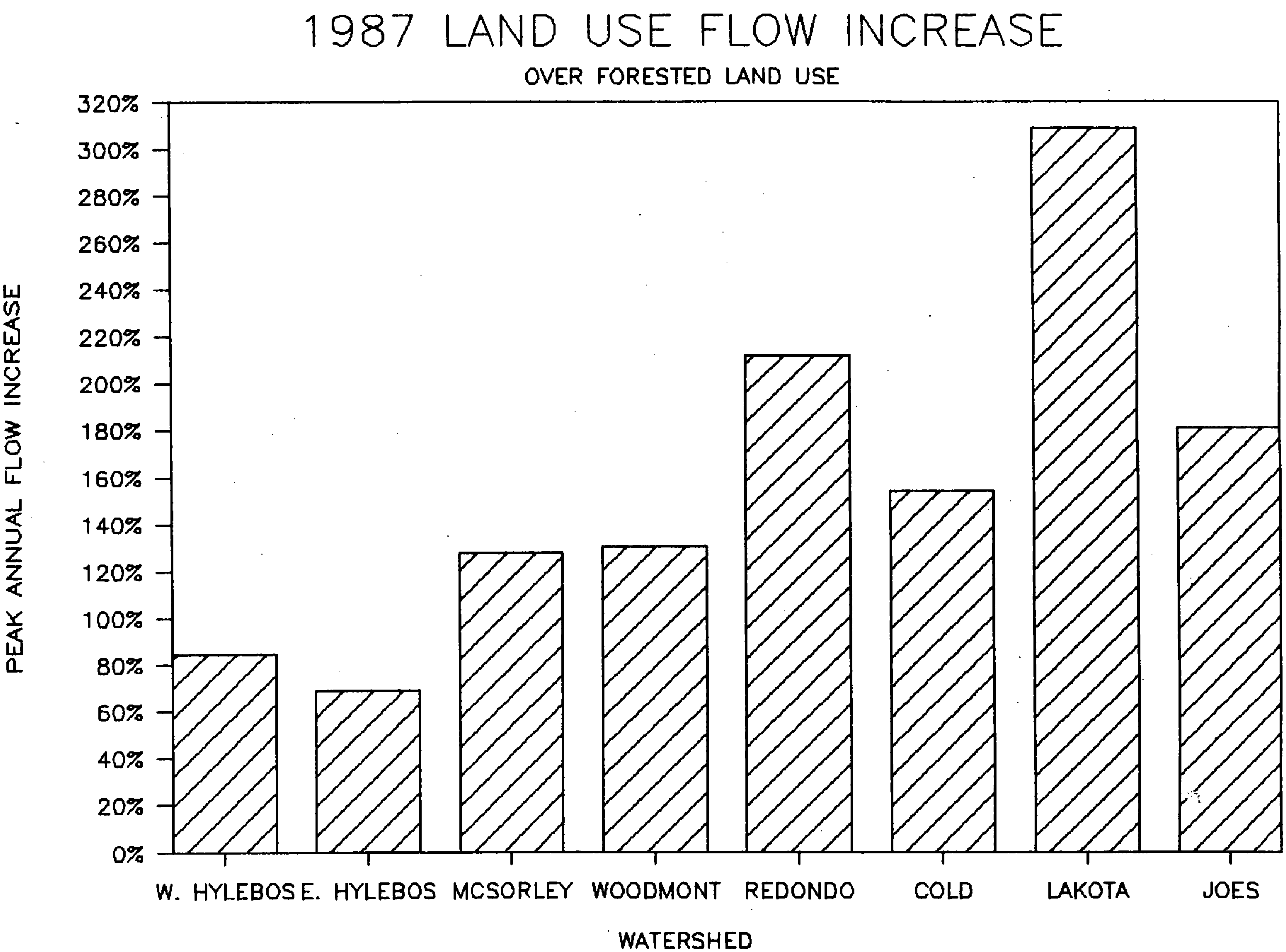
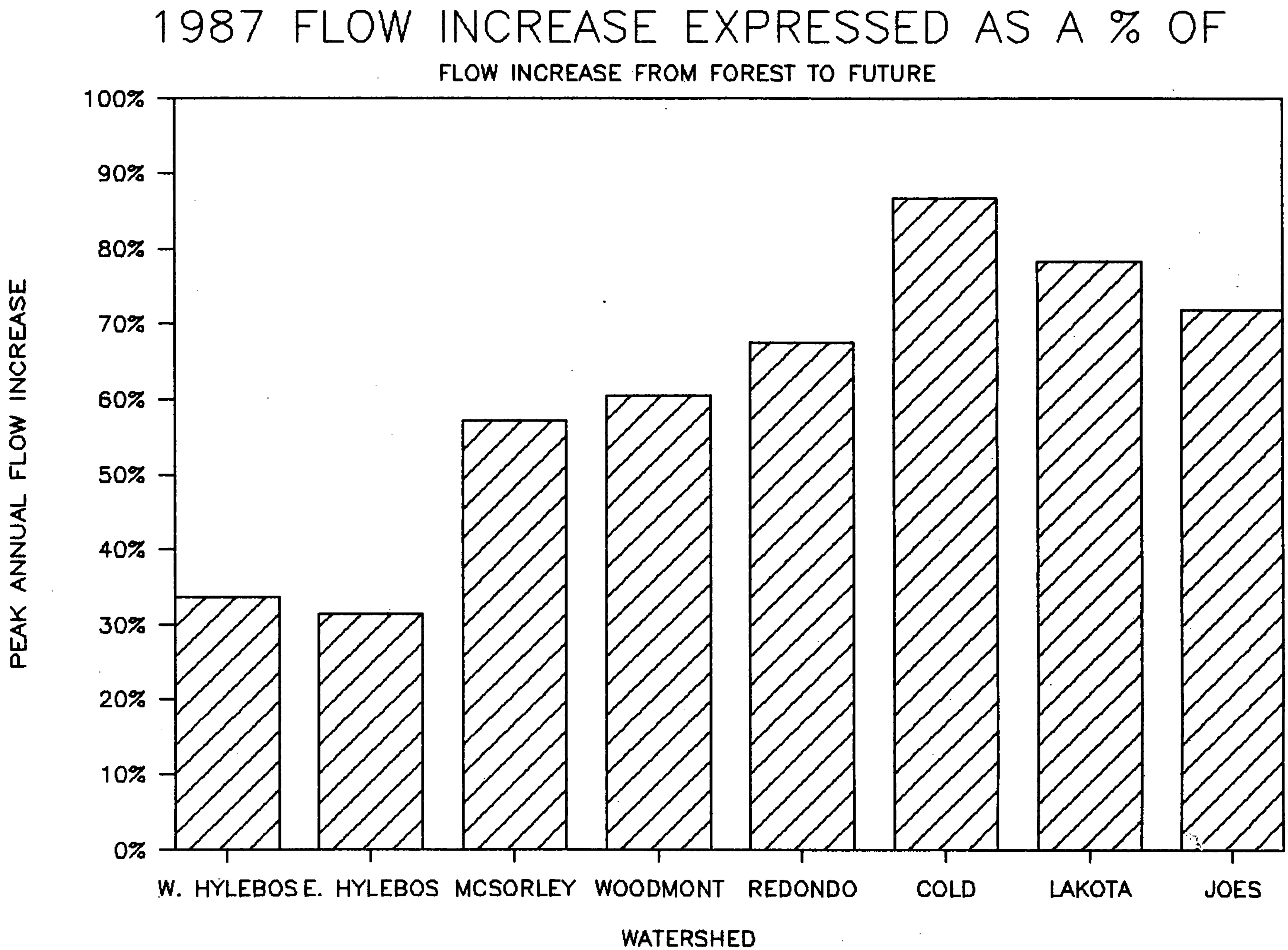


Figure 3.3.12



1987 LAND USE FLOW INCREASE
OVER FORESTED LAND USE
320%
300%
280%
260%
240%
220%
200%
180%
160%
140%
120%
100%
80%
60%
40%
20%
0%
PEAK ANNUAL FLOW INCREASE
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Figure 3.3.13



1987 FLOW INCREASE EXPRESSED AS A % OF
FLOW INCREASE FROM FOREST TO FUTURE
PEAK ANNUAL FLOW INCREASE
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
W. HYLEBOS
E. HYLEBOS
MCSORLEY
WOODMONT
REDONDO
COLD
LAKOTA
JOES
WATERSHED

Figure 3.3.14a

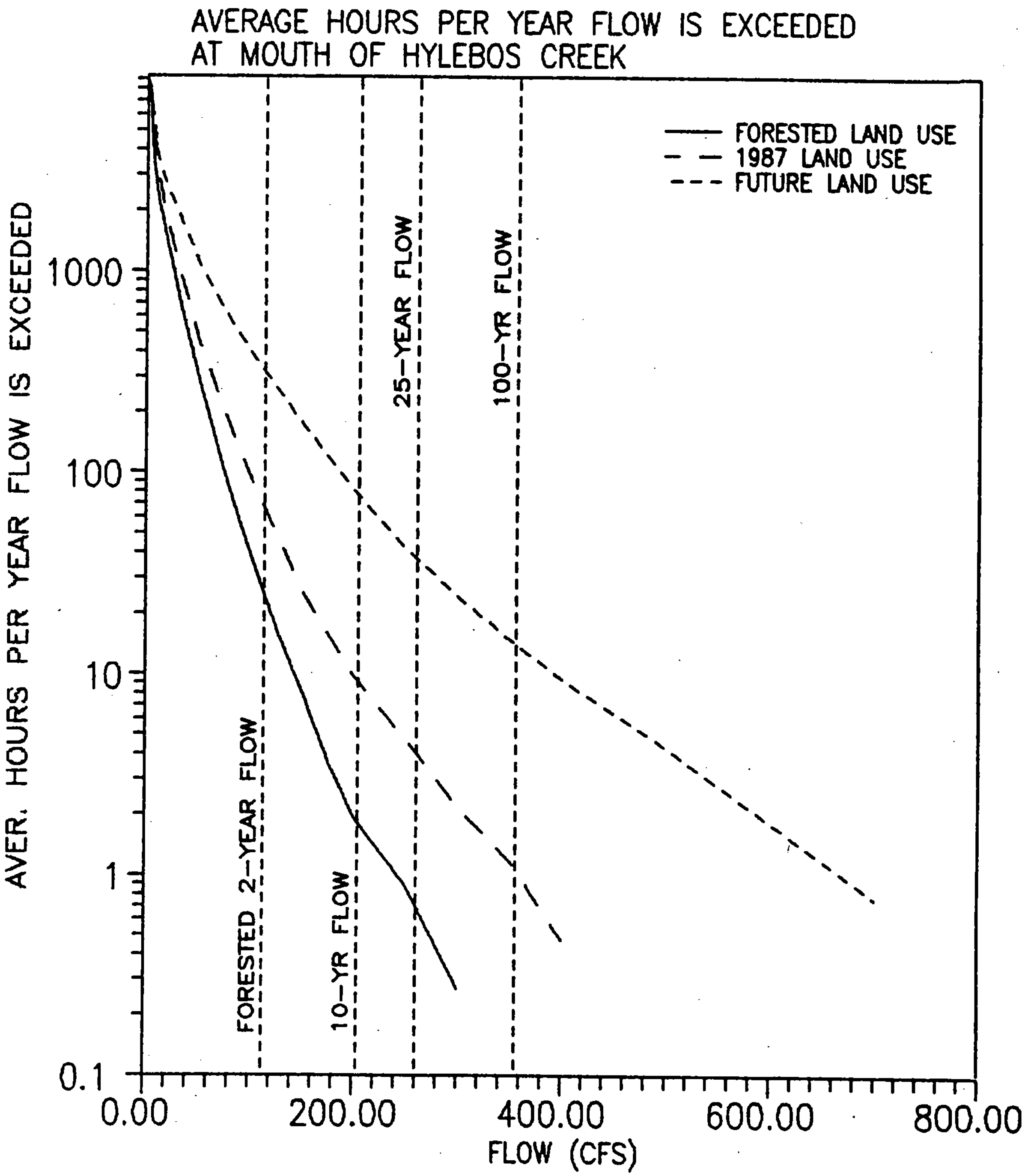
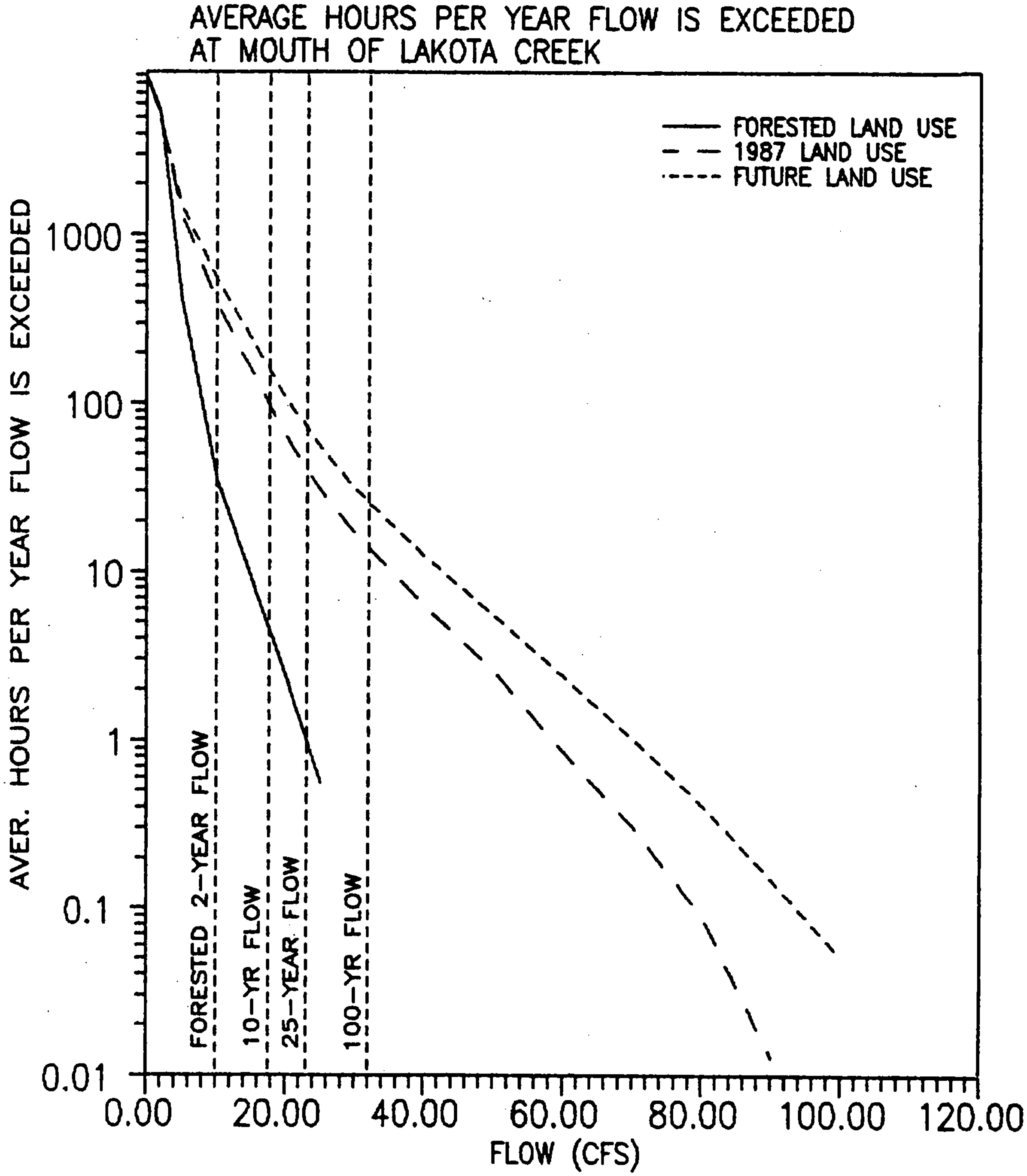


Figure 3.3.14b



Flow durations increase with urbanization because the number of flow peaks increase with urbanization. Figures 3.3.15a and b compare the number of flow excursions for the three land-use scenarios at the outlet of the Hylebos and Lakota Creek watersheds. A flow excursion is defined as the period when the hydrograph rises above a particular flow level, peaks, then drops below that flow level. It provides a rough estimate of the number of peaks that occur during a model simulation run. There are roughly 8-times as many forested 2-year excursions under 1987 land-use conditions as under forested conditions and 30 times as many under future land-use conditions. The difference between future and 1987 land-use is not nearly as great at the outlet of Lakota Creek compared to Hylebos Creek, another indication that the Lakota Creek tributary area is approaching built-out conditions.

Although the number of flow peaks at a given flow level increases with urbanization, each excursion occurs for a shorter period of time. Figures 3.3.16a and b compare the average length of time per excursion for the three land use scenarios. These figures show that the 2-year flow under the forested land use scenario occurs two to four times longer than under the future land use scenario. This is consistent with the concept of "flashy streams" under developed land-use conditions.

KEY FINDINGS

° Peak flow runoff at the 100-year level under 1987 land use ranges from 70 cfs to 290 cfs at the mouth of the creeks, with the East Branch Hylebos Creek producing the highest and Cold Creek producing the lowest discharge. Peak flow discharge per unit area is generally lower in the Hylebos basin, because the Hylebos basin has: 1) less intensive land use, 2) more lakes and wetlands, and 3) lower subcatchment gradients.

° During the analysis of the basins, a large storm event occurred on January 9, 1990 that caused severe flooding and erosion in much of the basin and was determined to be a 30-year 24-hour precipitation event. The recurrence interval for the 24-hour duration precipitation was 30 years and the 96-hour duration precipitation was 70 years. The runoff return period was determined from computer modeling to be between a 50-and 100-year recurrence interval at the confluence of the East and West Branches of the Hylebos Creek.

° Flow increases in the basins under future land use without mitigation ranged up to 200 percent over 1987 land use. The highest relative flow increases were noted along Joes Creek upstream of Twin Lakes, out of Panther Lake, along the West Branch Hylebos Creek, and from tributary 0015 to the East Branch Hylebos Creek. At the mouth of the creeks, higher flow increases were noted from Hylebos Creek than from the Lower Puget Sound creeks, a result of the lower level of current development in the Hylebos Creek basin.

° The Hylebos Creek and Lower Puget Sound basins represent one of the most heavily developed areas relative to other unincorporated areas in King County. Peak flows under 1987 land use have increased from 65 percent to 300 percent over the forested conditions that existed prior to this urbanization. Differences in peak flow runoff between the forested and 1987 land-use condition were greatest in the Lower Puget Sound basin, a function of the higher existing land use there.

Figure 3.3.15a

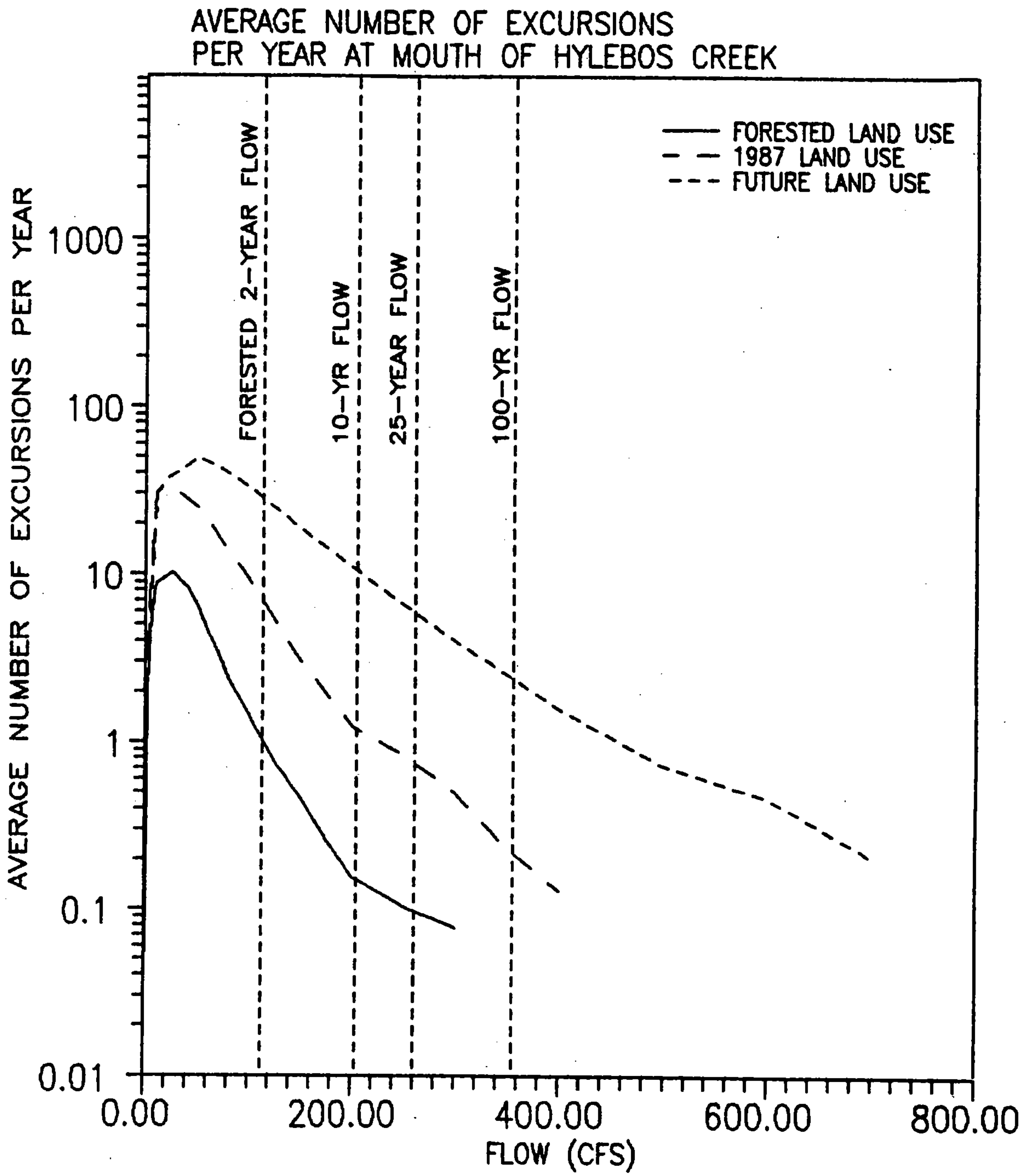


Figure 3.3.15b

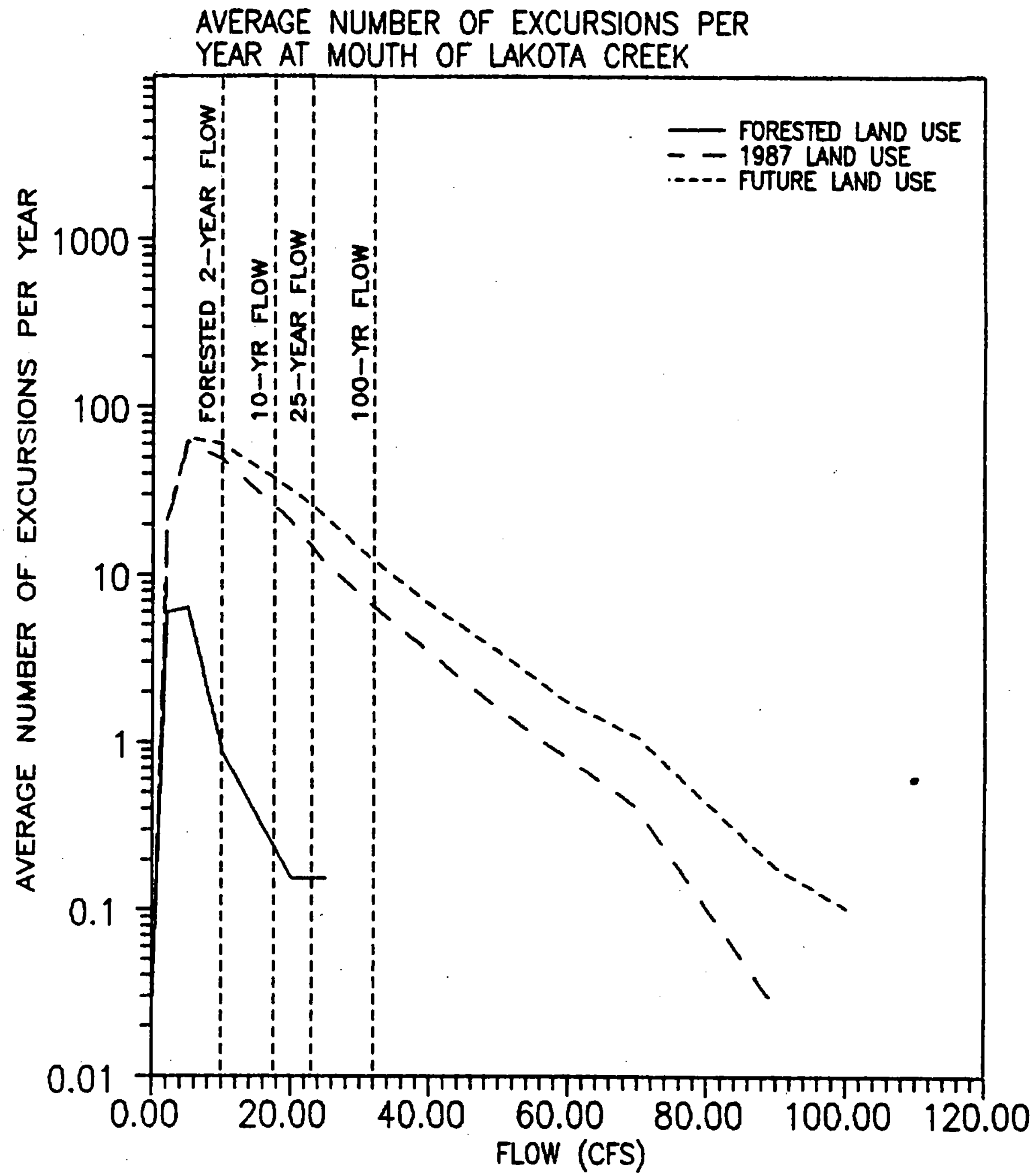


Figure 3.3.16a

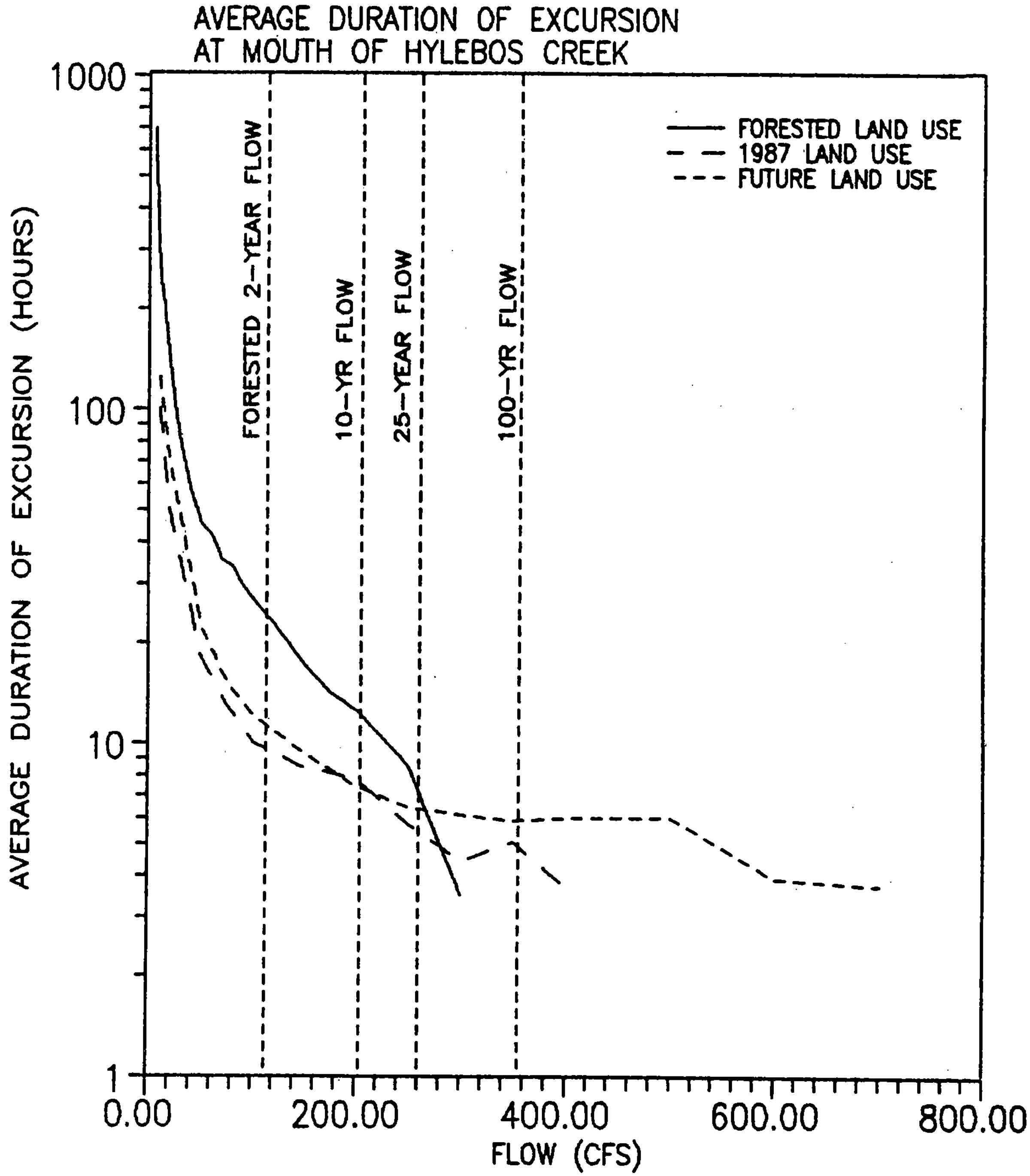
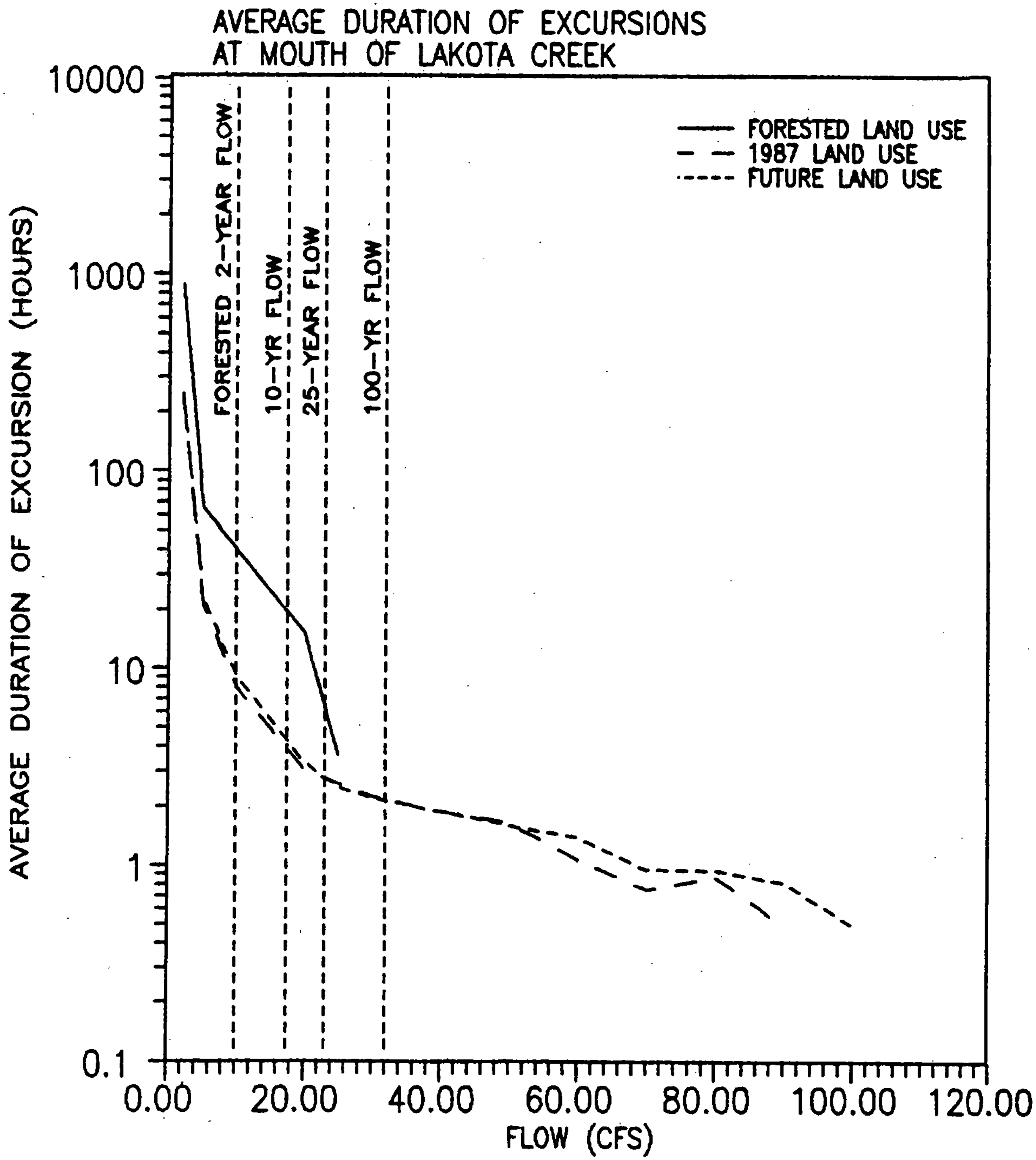


Figure 3.3.16b



SECTION 3.4 FLOODING

INTRODUCTION

The occurrence and extent of flooding in the Hylebos and Lower Puget Sound streams has been severely affected by urbanization. Overbank areas that were once available to accommodate high flood flows have been encroached upon, eliminating natural floodplain areas. The filling of wetlands has displaced water and eliminated off-channel storage areas. The capacity of soils to infiltrate has been greatly reduced by deposition of fine sediments as well as by the impervious surfaces of urbanization. As urbanization has continued, ever-expanding portions of the natural stream system are modified into a network of culverts, catch basins, and artificial ponds.

BASIC CONCEPTS

Types of flooding

Three types of flooding may occur in a basin: 1) regional - systemic, 2) local - systemic and 3) local - nonsystemic. Regional systemic flooding occurs when a large stream or river is the principal source of the flood waters. Typically, the stream or river has a large amount of tributary area that drains into a flat, broad floodplain. In an extreme flood event, the valley area would be inundated along a considerable length of its channel. The lower portion of Hylebos Creek from the upper end of the Hylebos Waterway to the confluence of the East and West Branches experiences this type of regional flooding. The portion of the West Branch in the vicinity of S 373rd Street also has a broad floodplain area that is susceptible to regional flooding. Regional flooding may be prevented by regulatory measures only if a basin has a considerable amount undeveloped land area. Reduction of existing regional flooding in a moderately urbanized basin such as Hylebos Creek would probably entail very expensive, complex projects such as large dams or levees.

Local flooding is characterized in two ways: small-scale, systemic flooding and nonsystemic drainage problems. Systemic flooding of small streams is similar to regional flooding but at a reduced scale. As with regional flooding, local systemic flooding is influenced by changes in land use. Flooding impacts may also be reduced with regulatory measures or the implementation of more limited-scale projects such as retention/detention (R/D) ponds and adequately sized culverts, bridges, or other structures. In the urbanized areas of Hylebos and the Lower Puget Sound basins, local flooding may be caused by increased runoff draining to undersized or debris-clogged culverts, or by channel diversions that supply additional volumes of water to streams that, under stable conditions, were naturally sized for smaller flows.

Urban areas also experience numerous drainage problems such as ponding at low points along gutters or parking lots, clogged inlets to catch basins, unmaintained private driveway culverts and downspout outlets that may temporarily pond water in yards. These types of drainage problems can also occur during storm events, but are not necessarily related to the stream system. These area-specific local nonsystemic problems are typically solved by localized improvements to the constructed drainage system.

Designated Floodplain Areas

Since the passage of the National Flood Insurance Act of 1968, the Federal Emergency Management Agency (FEMA) has identified many floodplain areas nationwide on Flood Insurance Rate Maps (FIRMs) (FEMA, 1985). No "Special Flood Hazard Areas" (areas within the 100-year flood boundary) have been identified on the King County FIRM in the Hylebos Creek and Lower Puget Sound basins. These basins have been designated as "Zone X". Zone X is considered an "area of moderate or minimal hazard from the principal source of flood in the area" (FIA 2, 1987). This designation applies to areas that lie outside the mapped 500-year floodplain.

Based on the flooding caused by the January 1990 storm, this designation appears to be appropriate. Flows calculated by computer modeling of the January storm were the most severe in the 39-year period of simulated flow record, and have been estimated as a 50- to 100-year runoff event. A Zone X designation does not exclude the possibility of flooding caused by storms that exceed the design capacities of the existing local drainage systems. Local stormwater drainage systems are not normally considered in flood insurance studies. However, the "failure of a local system creates areas of high flood risk within these rate zones" (FIA 2, 1987).

Flood insurance studies (FIS) of Hylebos Creek within Milton and unincorporated Pierce County were completed in 1981 and 1987, respectively. Each study used a 100-year discharge of 310 cubic feet per second as the flow just downstream of the confluence of the East and West Branches. This 100-year discharge is substantially less than the HSPF-estimated discharge of 556 cfs, which is the sum of the two branches under 1987 land-use conditions. The FIRM mapping shows I-5 as flood-free for the 100-year event. Recent experience indicates that the mapping does not reflect the actual flood boundaries. Although a measured discharge for the January storm is not available for a direct comparison, the recurrence interval was estimated to be less than a 100-year event and yet did cause flooding of two lanes of the freeway.

New flood analysis of the Pierce County portion of Hylebos Creek is included in the Stormwater Master Plan currently in preparation by James M. Montgomery and Associates for Pierce County Surface Water Management. The final plan is expected to be available in August 1990.

DATA GATHERING METHODS

The initial data gathering effort was focused on collecting and reviewing the existing drainage information about the basins. This information included King County SWM Reconnaissance Reports, currently proposed King County projects and studies, drainage studies from other agencies, such as Pierce County's 1974 Hylebos Basin Drainage Plan, FEMA Flood Insurance Studies, and anecdotal information from staff and citizens. Drainage complaints for the Hylebos Creek and Lower Puget Sound basins that are on file with the King County Drainage Investigation (DI) Section were reviewed and plotted on basin maps (1 inch = 1000 feet). Groupings and patterns of complaints were examined in an attempt to reveal systemic problems in the basins. Field investigations were conducted to examine the current physical state of the stream system. In some stream locations, limited topographic surveys were completed as an aid in understanding the hydraulic conditions of specific problem sites.

The most valuable source of information on flooding conditions in the planning area was the January 9, 1990 storm. In the Hylebos Creek and Lower Puget Sound basins, several roadways and homes were damaged by the flood waters. The storm was a first-hand demonstration of how the existing stream systems function under extreme flood conditions. During the flood event, King County SWM personnel toured throughout the basins to observe the flooding. Photos were taken at numerous locations and are on file in the SWM Basin Planning office. Area-specific locations of significant flooding problems are identified in the following discussion.

CONDITIONS

The Hylebos Creek basin has stream reaches that are prone to regional and local systemic flooding, whereas the Lower Puget Sound basin is mainly afflicted by numerous nonsystemic drainage problems. The Hylebos Creek basin suffered greater property damage and had more significant flooding problems in the recent flood events than the Lower Puget Sound drainages. In most cases, flooding during the storm not only was a result of increased volumes of water but also was caused by large cobbles and woody debris clogging culverts. Overall, areas typically plagued by flooding were once again inundated but to a much greater extent. New locations of flooding occurred in the Twin Lakes area and in the reach between Panther Lake and the West Hylebos Wetland. Since the last major storm event, which occurred in 1986, the upstream tributary areas of these two locations have had large amounts of recent development.

Based on past occurrences and the recent January storm event, several locations throughout the Hylebos Creek and Lower Puget Sound basins have been identified as significant problem areas. The areas are located on Figures 3.4.1a and b also are listed below. These problem areas are deemed significant because public safety was jeopardized and/or considerable property damage occurred. The numerous locations of ponded water in streets and yards where public safety was not significantly affected or property damage was slight are not enumerated in this report.

Current Significant Problem Areas

Fifteen locations have been identified as significant problem areas and are described below. Three regional flooding areas (Problem Numbers 1 - 3) are listed first and followed by the remaining twelve areas (Numbers 4 - 15) that are local systemic flooding problems. Further information is provided in this report in Chapter 4, Sub-basin Conditions.

1) Tributary 0006 near Interstate 5

   This is an area of regional flooding in the broad valley of the Lower Hylebos sub-basin in Pierce County, Milton, and Fife. During the January storm event, the two southbound lanes on the west side of I-5 were flooded for several days. Flow in this portion of the stream, approximately RM 4.6, is constricted by I-5, SR 99, the 70th Avenue E. bridge, and a recent fill of the right bank. This constriction, in combination with the moderately high tides that occurred during the storm (12.1 and 12.7 feet on January 9th and 10th, respectively), most likely increased flood levels throughout the valley.

Figure 3.4.1a

SIGNIFICANT FLOODING AREAS IN THE HYLEBOS CREEK BASIN

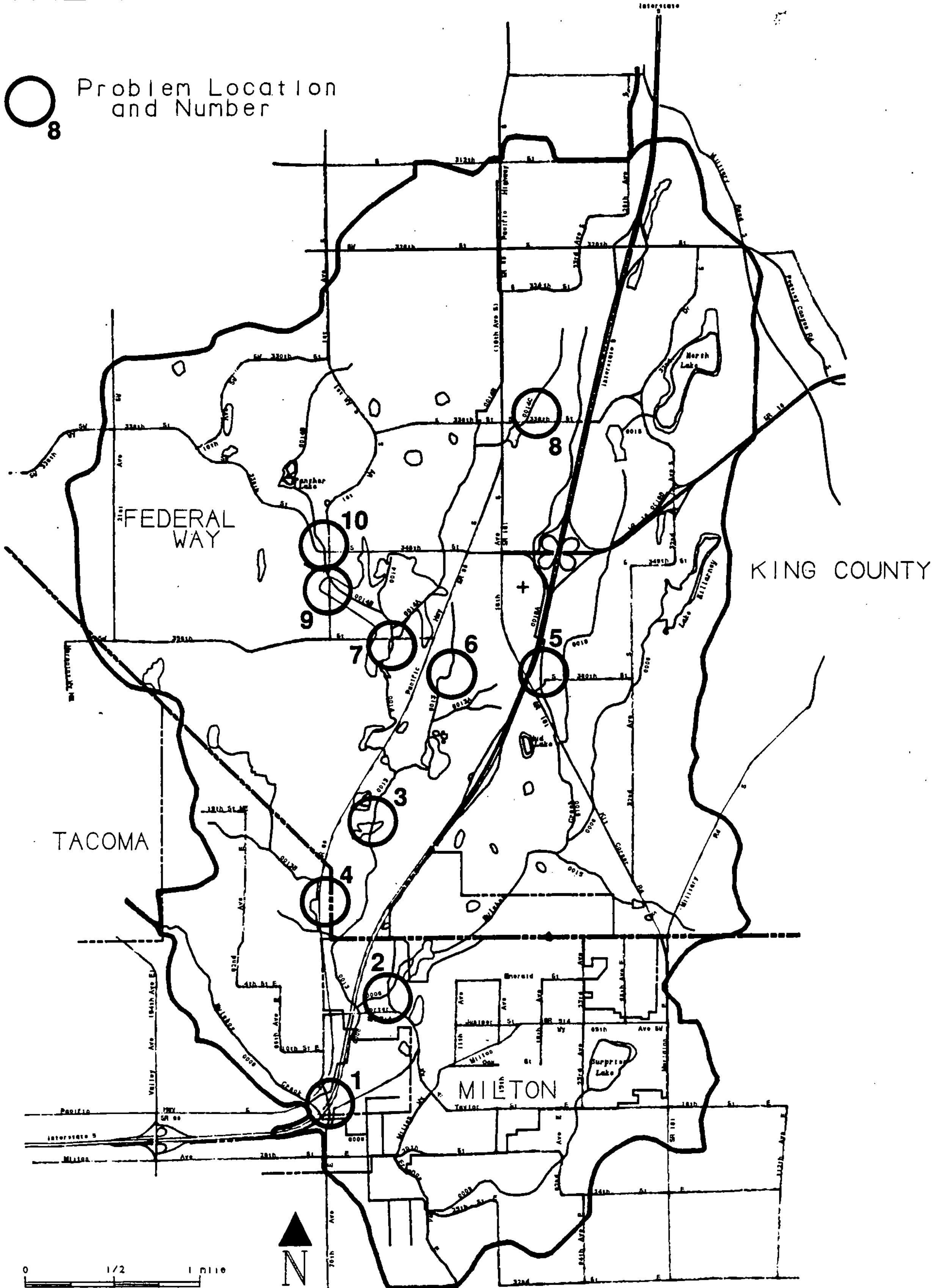
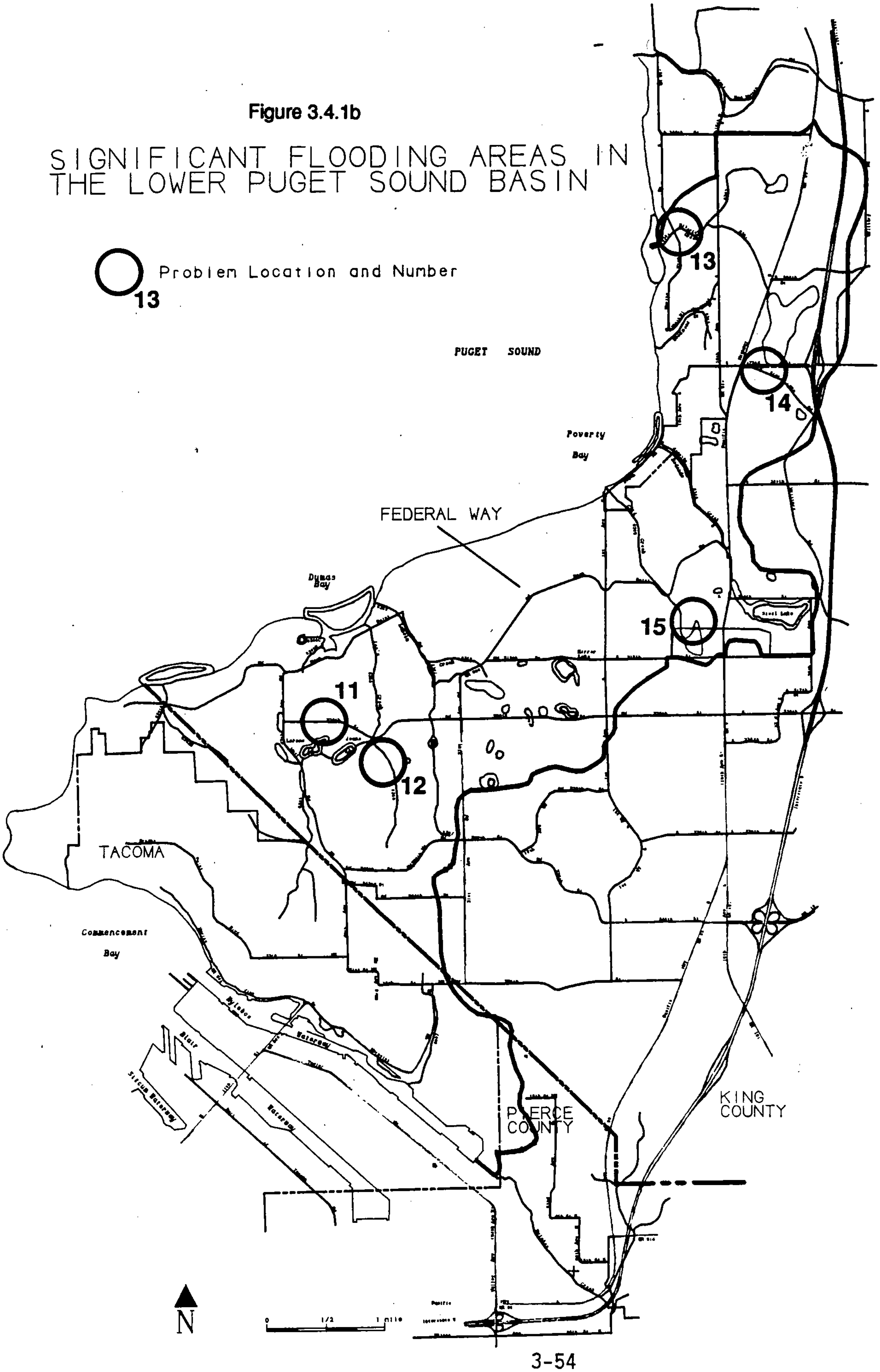


Figure 3.4.1b


SIGNIFICANT FLOODING AREAS IN THE LOWER PUGET SOUND BASIN
Problem Location and Number
13
PUGET SOUND
Poverty Bay
FEDERAL WAY
Dumas Bay
11
12
13
14
15
TACOMA
Commencement Bay
PIERCE COUNTY
KING COUNTY
N
0
1/2
1 mile

Preliminary results of a flood analysis of RM 0.00 to 2.33 indicates that the flat, broad topography of the valley area has a greater influence on flood profiles than the existing bridges and culverts along the creek. The analysis, being completed by James M. Montgomery (JMM) and Associates for the Pierce County Stormwater Management Plan, does not include the most recent HSPF flow estimates and only examines existing flow conditions. After analyzing culvert capacities, assuming the culverts are free of debris and sediment, JMM has determined that all bridges and culverts have adequate capacity for a 25-year flow event of 385 cfs. By comparison, the HSPF-estimated 25-year discharge for this area is 446 cfs under 1987 land use.

2) Tributary 0006 at 5th Avenue

Four homes near this culvert crossing in Milton were flooded during January 9, 1990. This area is the northeastern valley extension of the mainstem Hylebos Creek. The flat topography and the local hydraulic influence of the road culverts causes sediment deposition in the channel and culverts, reducing flow capacity. After the January storm, as much as 1.8 feet of silty sand was deposited in the 72-inch corrugated metal pipe and 0.4 feet in an adjacent 36-inch concrete pipe.

3) Tributary 0013 at S 373rd Street

This reach of Hylebos Creek undergoes regional flooding in the the broad floodplain valley that begins at the confluence with tributary 0014 (RM 1.55) and continues downstream one-half mile. The upper reach of tributary 0013 above the confluence has a relatively flat grade but tributary 0014 above the SR 99 crossing has a steeper gradient and carries large amounts of sediments from upstream sources into the valley below. Deposition of sediments in the channel has dramatically reduced the capacity of the stream and bridge, causing more frequent overbank flooding of adjacent pastures and one streamside home. Approximately 1,300 cubic yards of material were dredged from the bridge area in August 1986 but the influx of sediments continues. Prior to 1986, dredging was done every two years by King County Roads Maintenance Section.

During the January storm, streamside properties were severely damaged by large amounts of sediments deposited both upstream and downstream of S 373rd Street. The streamside home that was flooded on January 9th is located about 200 feet upstream of the bridge and approximately 10 feet from the stream's right bank. S 373rd Street, east of the bridge, also overtopped during the January storm. During a smaller storm in December 1989, neither the roadway nor the streamside home flooded. However, access to the home was blocked by flood waters that inundated the driveway and yard.

King County Roads Maintenance Section and three streamside property owners have requested Washington Department of Fisheries Hydraulic Project Applications to dredge the sediment from channel, upstream and downstream of the bridge, in the summer of 1990. This is considered an interim measure. The Draft Hylebos Creek and Lower Puget Sound Basin Plan will recommend long-term solutions for this and other problems.

4) Tributary 0013B at SR 99 near Swindell Road

This previously unnumbered tributary drains the northwestern portion of the Lower Hylebos sub-basin and joins with West Branch Hylebos Creek (0013) near RM 0.46. During the January 9th storm, sediments plugged both a 24-inch driveway culvert and a 24-inch cross culvert under SR 99. As water overtopped the highway, road shoulders were eroded. Large amounts of sediment carried downstream by the high flows were deposited into a wetland near the confluence of tributary 0013A and West Hylebos Creek (tributary 0013).

5) Tributary 0016A at S 363rd Place

A street and one home within a subdivision along 20th Place S and S 363rd Place were flooded on January 9, 1990. Tributary 0016A originally flowed to tributary 0013 in the West Hylebos sub-basin but was diverted during the construction of I-5 in the mid 1960s. After passing under I-5 through a 48-inch culvert (RM 0.68), tributary 0016A enters a 42-inch culvert at the north end of the subdivision at 20th Place S. During the January 9th storm, this culvert was continually clogged with debris despite local residents' efforts to clear it, and caused overtopping of 20th Place S. In addition, a very small R/D facility parallels the stream and 20th Place S. The retaining wall of the pond overtopped into the stream and also backed water onto 20th Place S.

6) Tributary 0013 at S 359th Street

This two-lane roadway was overtopped and partially washed out in the January 9th event. Overtopping occurred because the culvert became clogged with debris. Flow over the pavement eroded and undermined the downstream embankment, leaving less than one lane of roadway. The road has been closed by the King County Roads Division pending repair. King County has coordinated with the Washington Department of Fisheries to obtain the Hydraulic Project Application (HPA). According to the HPA conditions, culvert replacement and road repairs may begin after June 15th of this year.

7) Tributary 0014 at S 356th Street

Two 36-inch culverts at this crossing carry the outflow from the West Hylebos Wetland. Flood flows in December 1989 and January 1990 overtopped the road, washing out both shoulders.

8) Tributary 0014C at S 336th Street

Two houses were flooded when this roadway (RM 0.34) and SR 99 (RM 0.15) were overtopped during the January 9th storm. The top-ranked Basin Reconnaissance capital improvement project is located between these two locations, at King County inventoried Wetland 9. The project goals are to reduce chronic flooding and improve water quality (further information on this and other scheduled Capital Improvement Projects is listed below in the section, "Current Projects and Studies").

9) Tributary 0014B at 1st Avenue S

From S 348th Street, the stream parallels 1st Avenue S prior to entering an 18-inch culvert under SW 353rd Street, then crosses 1st Avenue S via a 21-inch culvert that outlets to the West Hylebos Wetland. This tributary is a new channel and has been created by recent surface outflows from Panther Lake, which historically infiltrated nearly all flows. During the January storm, outflow from Panther Lake overwhelmed both culverts and severely eroded the channel between S 348th and SW 353rd Streets. The sidewalk along 1st Avenue S was undermined and the channel was dramatically widened from an average pre-flood width of five feet to a width of at least 20 feet. The 1st Avenue S and SW 353rd Street intersection was flooded, and road shoulders on both streets were washed out. A sanitary sewer line and manhole at the intersection were also flooded by stormwater.

10) Tributary 0014B at SW 336th Street

SW 336th Street, just west of 1st Avenue S, was flooded during the January 9th storm. The outlet structure at Panther Lake became clogged with debris, causing overtopping of the berm road at the southern end of the lake. Downstream of the berm road, the tributary is carried under SW 336th Street by two culverts (36- and 30-inch). The 36-inch culvert also become clogged with debris, causing flooding of a portion of SW 336th Street that parallels the stream. SW 336th Street at the culvert alignment was not overtopped. The estimated flow capacity of these culverts, when clear of sediment and debris, is approximately 200 cubic feet per second. The actual flood discharge, which caused significant downstream flooding and erosion (item 9, immediately above), would have been less than 200 cfs because of the debris restricted flow in the 36-inch culvert.

11) Tributary 0388 (Joes Creek) at Lorene Lake and Jeane Lake.

These lakes, commonly referred to as Twin Lakes, are fed by tributary headwaters that lie in Pierce County and Tacoma. Past and current construction of subdivisions in the headwaters area has delivered significant quantities of sediment into both lakes, possibly reducing the flood storage capacity. The most recent upstream activity, in October 1989, included clearing of approximately 120 acres of forested land. In previous years, flooding around the lake perimeters has occurred. During the January 9th storm, however, at least 4 houses that were flood-free in the past were flooded for the first time. Flooding around the lakes' perimeters may have been exacerbated by earlier storms that raised lake levels prior to the January storm.

12) Tributary 0389 in Olympic View Park

This tributary (RM 0.20 to 0.60) has undergone chronic erosion and has flooded at least four times in the last five years. Drainage from approximately 700 home sites and the adjacent streets flow into this ravine. Existing gabion weir dams with overflow structures were built in 1986 as a County project to reduce velocities and stabilize the channel. High flows in January caused erosion downstream of the weirs and flooding of SW 325th Street. Debris clogged the inlet structure to the culvert system that passes between residences and under SW 325th Street and caused flows to overtop a small berm at the inlet.

13) Tributary 0381 in Salt Water State Park

In January 1990, the Park underwent severe flooding, with large depositions of sand and gravel in the stream channel, on park grounds, and in the delta into Puget Sound. Specific information on damages and the extent of the January flooding is presently unavailable. The Washington State Parks and Commission, and the City of Seattle are currently investigating the flooding patterns of the stream. Recent modeling of stream flows has been completed by the City for the design of a retention/detention pond for the Midway Landfill. The pipe outlet of the retention/detention pond enters tributary 0382 near 16th Avenue S, just upstream from the Park boundary.

14) Tributary 0381 at S 272nd Street and Star Lake Road

This area is currently the subject of King County SWM Drainage Investigation flood study (further details are provided in the section, "Current Project and Studies", below). Yearly complaints have been filed related to street flooding and malfunctioning retention/detention ponds.

15) Easter Lake near S 312th Street

Flooding around the perimeter of the lake has been a chronic problem. Specifically, the Evergreen Retirement Manor at 14th Avenue S has experienced flooding three times in the last 5 years. During the January 1990 storm, the first floor of the Manor was flooded but evacuations were not necessary. S 312th Street, on the southside of the lake, was also flooded during the January storm.

Other areas of roadway flooding during the January storm include:

- S 320th Street between SR 99 and 23rd Avenue S
- Tributary 0014 at S 348th Street near 11th Avenue S
- Tributary 0006 at SR 161 near S 370th Street
- Tributary 0016 at SR 161 near S 368th Street
- Tributary 0014C at S 330th Street and 20th Avenue S
- Headwater areas of tributaries 0014A and 0014C near S 317th Street between 20th and 23rd Avenues S
- Tributary 0384 at 4th Place S near Redondo Beach
- Adelaide Beach along 20 Place S (no tributary number)
- Lake Ponce De Leon near SW 324th Street and 26th Avenue SW
- SW 337th Street and 21st Avenue SW (malfunctioning commercial infiltration pond)
- Tributary 0016A southwest of the I-5 and S 348th Street interchange (behind Costco)

Current Projects and Studies

Efforts toward resolving flooding problems in the basins include capital improvement projects and drainage studies completed by the SWM Project Management and Design (PM&D) and Drainage Investigation (DI) sections. Some DI studies are initiated as a result of problems identified during inspections by SWM Facilities Maintenance personnel. The King County Roads Division has several projects in progress that have drainage design components. The Hylebos Creek and Lower Puget Sound Basin Plan, of which this conditions report is a preliminary analysis, will provide substantial new information and analysis to resolve long-range flooding problems. Because of the recent incorporation of Federal Way, continuation of work on these projects and studies will be determined through interlocal governmental agreements between King County and the City.

1) King County SWM Capital Improvement Projects

The King County Council has adopted a six-year capital improvement program (CIP) which is updated annually. Currently, the CIP list includes two projects in the Hylebos Creek basin (Kitt Corner Regional Pond and S 336th Street "South" Pond) and one project in the Lower Puget Sound basin (Lakota Detention Pond). Both Hylebos projects were identified in the 1979 Pacific Highway South Drainage Study completed by Kramer, Chin and Mayo for the King County Hydraulic Division. King County will design these projects by the end of 1990; Federal Way has subsequent responsibility for construction. King County, by enforcing a permit violation, will also oversee a culvert replacement on tributary 0014A at about RM 1.20 that will provide de facto detention just upstream of the S 336th Street project site. The violation was for the removal of a culvert that was functioning as the outlet control of a wetland.

Final design of the Lakota project will be completed in the first half of 1990 and provided to Federal Way. If constructed, the Lakota project would reduce erosion in the downstream reaches of tributary 0386 and prevent flooding of the ballfields, which currently occurs annually. The Lakota and Hylebos projects are utilizing the results of the HSPF model and will be designed to accommodate predicted flow under build-out land use. Since the incorporation of Federal Way, three additional County road-widening projects are now the responsibility of the City:

2) King County SWM Drainage Investigation (DI) Studies

Drainage Investigation receives an average of 700 drainage complaints per year throughout King County. About ten percent of these complaints result in enforcement action due to violations of the County Code. The remaining complaints are directed to appropriate agencies that have jurisdiction or the complaint is determined to be a private problem in which the citizen can only resort to civil action. Drainage Investigation has received at least 650 complaints related to the January storm event alone. For the week of January 8, 1990, three hundred and eighteen complaints were filed, in comparison to only 60 complaints filed during the week of December 4th in 1989 when a moderate winter storm occurred.

In addition to handling complaints, DI performs small-scale drainage studies to analyze flood problems and develop retrofit designs for existing retention/detention ponds. Studies in progress in 1989 included:

a) Star Lake Road and S 272nd Street

b) Alderbrook Division 1, Pond 1 - 1400 SW 323rd Street

c) Lakota Ridge - 22nd Avenue SW and SW 310 Place

d) Lakota Highland - SW 306th Place and 22nd Avenue SW

e) Marlbrook Division 1 - S 293rd Place and Redondo Way S

Due to staff assignments to field investigations of complaints related to the January storm, the Star Lake study was temporarily on hold. The study is now in progress and is expected to be completed by the end of this year. The other four areas listed above are retrofit studies, now in Federal Way, and are currently on hold. No studies have yet been initiated that address new problems related to the December 1989 and January 1990 storms.

3) King County SWM Facilities Maintenance (FM) Section

This section is responsible for the inspection and maintenance of residential R/D facilities throughout the SWM service area. Typically, a residential facility is inspected at least once a year by one of four inspectors. Currently, there are at least 20 residential R/Ds in the Hylebos Creek basin and 62 in the Lower Puget Sound basin. Through the inspections, design and maintenance problems are identified that may initiate retrofit studies such as those listed above in item 2).

SWM FM also inspects commercial R/D facilities but the maintenance of the facility is the responsibility of the property owner. Due to the limited staff of inspectors, commercial facilities are visited about every 1-1/2 years.

Regional R/D facilities such as the five West Campus retention ponds are inspected and maintained by the King County Roads Maintenance Section. However, these activities are funded by the SWM Division. Inspection of regional R/Ds usually occurs yearly during the dry summer months.

4) King County Roads Division Projects

Several road widening projects, which have surface water drainage components, have been proposed by the King County Roads Division to increase pedestrian and traffic safety. The project locations and current status are listed below.

a) Redondo Seawall and Beach Road S (in environmental review)

b) SW 356th Street between 21nd Avenue SW and 1st Avenue S (final design)

c) 16th Avenue S between SR 99 and S 348th Street (preliminary design)

d) S 356th Street between 1st Avenue S and SR 99 (preliminary design)

e) S 272nd Street between SR 99 and 500 feet west of 16th Avenue S (preliminary design)

Since the incorporation of Federal Way, three additional County road-widening project are now the responsibility of the City:

f) S 356th Street between SR 99 and SR 161

g) S 312th Street between SR 99 and 28th Avenue S

h) Southwest 312th Street between 1st Avenue S and SR 509

Anticipated Future Flooding Problems

Significant flow increases are predicted to occur from increased amounts of impervious surfaces within the Hylebos Creek and Lower Puget Sound basins. As discussed earlier in this report, the Hylebos Creek basin will have greater increases in peak flows than the Lower Puget drainages. The larger flow increase in the Hylebos Creek basin is a reflection of the relatively undeveloped 1987 conditions and the higher intensity land uses. Increased flows will exacerbate current flooding problems as well as cause flooding in previously flood-free areas. A concomitant of increased peak flows is increased frequency, causing flooding to occur more often. Increased flows and frequencies will result in greater amounts of property damage, more frequent maintenance, and a higher risk to public safety.

In order to evaluate the effect of increased flows on those areas identified previously as significant current flooding problems, culvert and bridge capacities were determined. Culvert capacities for problem numbers 3 and 5 - 10 were compared to HSPF-estimated 1987 and future 25-year flows. Culverts must be designed to pass the flow with a 25-year recurrence interval, according to the 1990 King County Surface Water Design Manual. For problem number 3, S 373rd Street, the King County Design Manual requires 100-year flow bridge capacity. Table 3.4.1 shows the estimated capacities and the predicted 1987 and future flows for these sites. One of the seven sites was adequate for existing flows, but none of the sites can accommodate future, unmitigated flows. The estimates of capacities assume that culverts and bridges are free of debris and sediment. If a bulking factor of fifty percent were applied in the analysis to account for reduction caused by debris (ASCE, 1969), none of the seven sites could pass the estimated 1987 flow.

Replacement of undersized culverts is currently proposed for three of the eight sites. An upgrade of the culvert under S 359th Street from an 18-inch concrete pipe to a 55 x 73 inch arch will accommodate the existing and future flows. Problem number 8 at S 336th Street is also slated for an upgrade as a component of the SWM capital improvement project. Assuming this occurs, the culvert will be designed to pass future flows and the design will include an overflow structure to protect the road embankment. Similarly, the King County Roads project on S 356th Street (problem number 7) would also be designed in this manner.

The remaining problem areas where capacities were not estimated are complex drainage issues that are currently under study (problem numbers 1, 11 and 14) or would require detailed investigations (problem numbers 2, 12, 13, and 15) to fully understand the site hydraulics. One location (problem number 4) lies within Pierce County and was not within the HSPF model study area.

Results of the HSPF hydrologic analysis show that future flows will increase over 150 percent in three Hylebos Creek subcatchments (WH7, WH13, and H2) and two Lower Puget Sound subcatchments (J6 and J8). Flooding downstream of Panther Lake (subcatchments WH7 and WH13) now occurs during large events and is predicted to occur annually under future flow conditions. Historically, Panther Lake infiltrated all flows and contributed no surface flow to tributary 0014B.

Table 3.4.1

FLOW CAPACITY INVESTIGATION FOR THE 25-YEAR EVENT

Problem No.	Problem Location	Tributary No.	Subcatchment No.	Estimated Capacity (in cfs)	Existing 1987 Flow (in cfs)	Future Flow (in cfs)	Adequate for Existing Flow	Adequate for Future Flow
3	S 373rd St.	0013	WH2	284	217.0	427.0	YES	NO
5	S 363rd Pl.	0016A	H9	55	73.8	120.0	NO	NO
6	S 359th St.	0013	WH3	30	74.2	130.0	NO	NO
7	S 356th St.	0014B	WH UW	100	129.0	306.0	NO	NO
8	S 336th St.	0014C	WH10	41	57.0	79.9	NO	NO
9	1st Ave. S	0014B	WH7	11	18.0	153.0	NO	NO
10	SW 336th St.	0014B	WH7	200	18.0	153.0	NO	NO

NOTES:

1) All existing and future flows listed are 25-year events except problem number 5, which is the 100-year.

2) All capacities were estimated assuming the culverts and bridge were clear of debris and sediment.

3) Estimated capacity for problem number 5 represents downstream culvert crossing at SR 161.

During the January 1990 storm, outflow from the lake occurred because land-use conditions in the tributary area have changed and because of reduced infiltration in the lake bottom. This more closely reflects future flow modeling, which predicts a 100-year, unmitigated lake outflow of nearly 200 cfs. This predicted increased future outflow from Panther Lake will exacerbate existing flooding in downstream reaches (see problem numbers 3, 7, 9 and 10). Recent land-use changes in the headwaters of Joes Creek caused similar flooding to the Twin Lakes area (subcatchments J6 and J8) during the January 1990 storm (problem number 11).

The most dramatic change in flooding conditions will occur in those areas that under current conditions are flood-free but will experience over a 2-fold increase in future peak flows. Two areas of concern are the East Branch Hylebos Creek (tributary 0016) downstream of North Lake in subcatchments H10 and H11, and a tributary (0015) to the East Branch within subcatchment H2. In the North

Lake area, the two-fold increase reflects relatively small quantities of flow and thus damage potential is limited. For example, the 100-year discharge of subcatchment H10 will increase from 17.4 cfs under 1987 conditions to 31.9 cfs. Farther downstream along tributary 0016, however, subcatchment H8 has a lower percentage increase but a much larger discharge for the same event (70.5 cfs and 117.0 cfs, respectively), mainly because of the conversion of forested areas to urban land uses. Residential development currently under construction along tributary 0016 south of SR 18, and existing residential areas just upstream of the SR 161 culvert crossing, could experience severe flooding if these future flows are not mitigated. Future overtopping of SR 161 at the tributary 0015 culvert crossing is also expected to occur because of greatly increased runoff from subcatchment H2.

KEY FINDINGS

° Fifteen locations within the Hylebos Creek and Lower Puget Sound basins currently experience significant flooding problems. At least six of these sites have culverts or bridges that when clear of debris and sediment, are undersized for the HSPF-estimated 1987 flows.

° The Panther Lake and Twin Lakes areas currently experience flooding that approaches future conditions flows because of significant land-use changes that have occurred since 1987. Subsequent increases in future flows from the Panther Lake area will increase the extent of flooding along the entire stream length of West Branch Hylebos Creek.

° Although existing flooding problems will worsen throughout the basins with future increases in impervious surfaces, the most significant change in flooding conditions will be the occurrence of chronic, severe flooding at locations that currently are not flood-prone. The two locations most likely to experience future flooding are in the East Branch Hylebos Creek sub-basin, along tributary 0016 downstream of the Weyerhauser Pond (subcatchments H8) and along tributary 0015, east of Milton (subcatchment H2).

SECTION 3.5 GROUNDWATER

INTRODUCTION

Groundwater plays a variety of roles in the hydrologic function of the basins. By definition, groundwater is water that is found in zones of saturated geologic material beneath the surface. In the non-urbanized parts of the basins, far more of the water falling as precipitation moves as groundwater rather than as surface water. That water returns to the surface as springs and seeps, providing baseflow for perennial streams; it also provides drinking water to this rapidly growing area.

Because of the importance of groundwater, a regional groundwater study was initiated by a consortium of government agencies and water purveyors in the south King County area in 1986. Its first report, stressing existing data and future analytical needs, was issued in 1989 and provides the basis for the following discussion (South King County Ground Water Advisory Committee, 1989). That report in turn has depended on a variety of sources, including numerous existing water-well drilling records, recent exploration wells, historical water-use and water-quality data, recent U. S. Geological Survey monitoring, and geologic mapping done for this basin plan.

CONDITIONS

Main Aquifers

Although groundwater exists by definition in all saturated geologic materials, it is accessible for water use or discharge to surface-water bodies only where it can move freely through those subsurface deposits. These freely transmitting deposits are characterized by relatively large pores and are known as aquifers. In the Hylebos Creek and Lower Puget Sound area, they are commonly deposits of sand and gravel. In contrast, deposits that restrict the movement of groundwater are called aquitards (if their are moderately restrictive) or aquicludes (if they are strongly restrictive). Their composition is dominated by silt and clay. The layering of geologic deposits in these basins has left a vertical sequence that includes successively deeper aquifers and intervening aquitards and aquicludes.

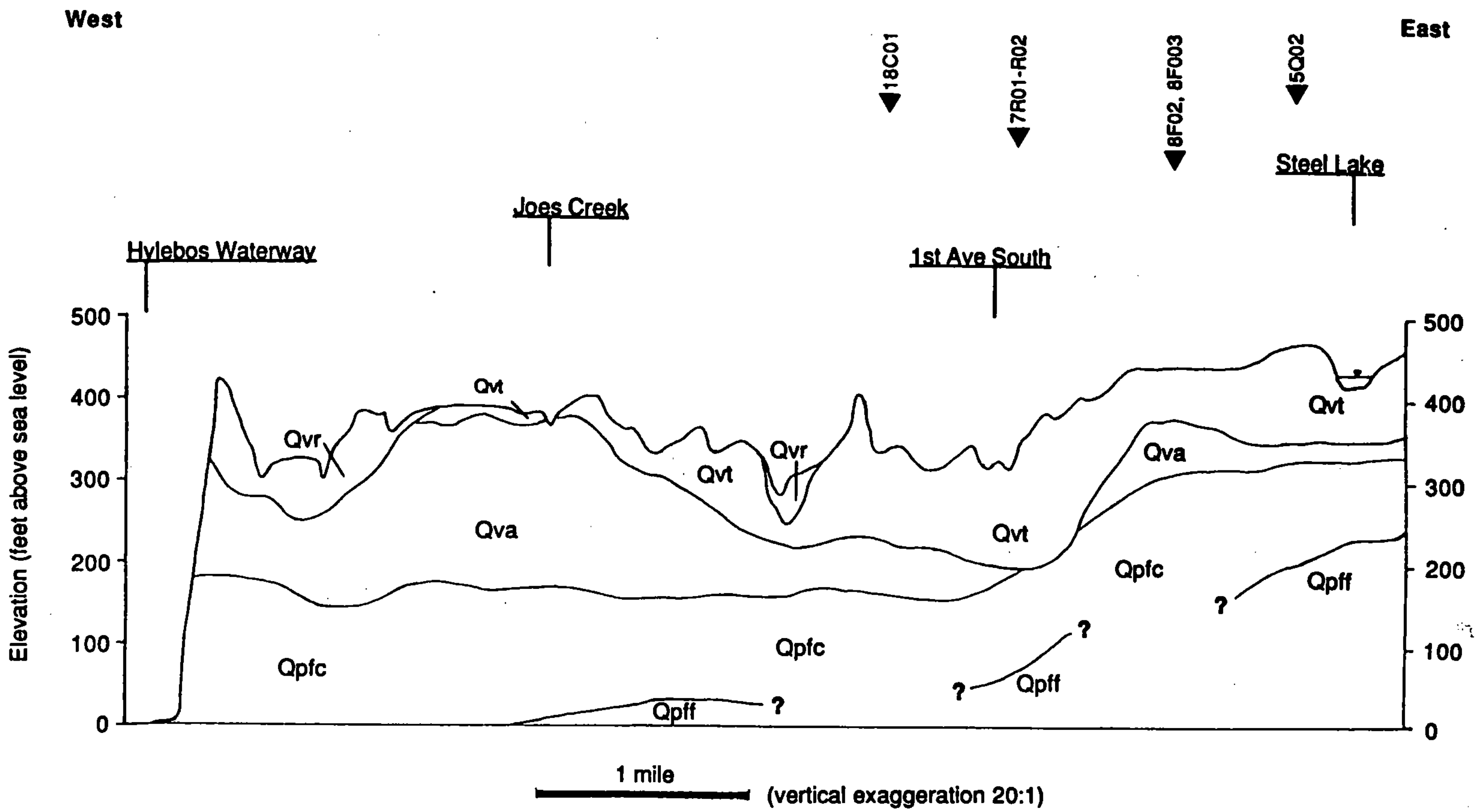
Although some of the deep aquifers may be significant for water supply, the shallower aquifers are particularly important to this basin plan. They are directly connected to lakes and streams; and to date, they have also been the aquifers most intensively used for water supply.

Two distinctly mapped geologic deposits, which may be partly connected hydrologically beneath the surface, form the main shallow aquifer zone in this area. The Vashon advance outwash, found primarily in the western part of the plan area, and older sand and gravel, located in the northern and eastern part of the plan area, compose this zone (see Figure 3.5.1). Both deposits are capped with relatively impervious till over most of the basin area, and so they are partly isolated from both surface-water contamination and direct recharge.

The Vashon advance outwash is concentrated in an area that extends south and east from Dumas Bay and Dash Point through the lower East Branch Hylebos Creek

Figure 3.5.1

GENERALIZED STRATIGRAPHY
HYLEBOS BASIN



DESCRIPTION OF MAP UNITS (FIG 3.2.1)

HOLOCENE DEPOSITS

POSTGLACIAL DEPOSITS (HOLOCENE) - Divided into:

Modified Land (m)

Beach Deposits (Qb)

Wetland Deposits (Qw)--Localities are compiled from the King County Wetland Inventory (1983).

Alluvium (Qal)

Landslide Deposits (Qls)--Only four are sufficiently large to show at map scale; smaller such features are common along many of the wave-steepened beach cliffs.

Mass-Wastage Deposits (Qmw)--Colluvium, soil, or landslide debris with indistinct morphology, mapped where sufficiently continuous and thick to obscure underlying material.

Older Alluvium (Qoal)--Similar in texture and morphology to unit Qal. May represent a late stage of deposition during the time of Vashon ice recession.

PLEISTOCENE DEPOSITS

DEPOSITS OF THE VASHON STADE OF THE FRASER GLACIATION (PLEISTOCENE) - Divided into:

Recessional Outwash Deposits, Lacustrine (Qvrl)--Laminated to massive silty clay to clayey silt, deposited in standing water during a late stage in the ice recession.

Recessional Outwash Deposits, Undifferentiated (Qvr)--Stratified sand and gravel, moderately to well sorted, with less common silty sand and silt.

Ice-Contact Deposits (Qvi)--Similar in texture to unit Qvr but containing a much higher percentage of silt mixed in with the granular sediment.

Till (Qvt)

Advance Outwash Deposits (Qva)

PRE-FRASER DEPOSITS (PLEISTOCENE)- Divided into:

Pre-Fraser Deposits, Fine-Grained (Qpff)--Laminated to massive silt, clayey silt, and silty clay, with or without interbedded sand and uncommon gravel.

Pre-Fraser Deposits, Coarse-Grained (Qpfc)--Interbedded sand and gravel with at most minor layers and lenses of silty sand and silt; moderately to heavily oxidatidized. Weathering rinds are common but not ubiquitous and range from 0.1-0.3 mm on fine-grained volcanic clasts.

Till, Undifferentiated (Qtu)--Compact, stony diamict, distinguished from its Vashon-age equivalent by oxidation of clasts and matrix, rare weathering rinds on clasts up to 0.5 mm thick, and stratigraphic and topographic position. Includes fluvial, lacustrine, and mudflow deposits too thin to discriminate at map scale.

and into the Milton area. It is penetrated by numerous water-supply wells along its entire length and is commonly known as the "Milton-Redondo Channel" in the hydrogeologic literature of the area (Robinson and Noble, 1987). Its major surface exposures are limited to coastal hillsides at the channel's northern end, which locally extend down to sea level; "windows" through the overlying till along the upper reaches of tributaries 0388 and 0389; and along the valley walls of the East Branch Hylebos Creek (see Figure 3.2.1). Elsewhere in this zone, it is continues but entirely subsurface.

The older sand and gravel deposits are exposed both beneath the Vashon advance outwash along the Hylebos Waterway and directly beneath Vashon till in the Des Moines, Midway, and Redondo areas. Surface exposures are found only along Des Moines Creek (just north of the plan area) and on hillsides and in stream valleys above Puget Sound. Excavations now occupied by the Midway Landfill also penetrated into this deposit.

Groundwater Flow Directions and Recharge

As in many other systems, the natural groundwater flow crudely mimics the pattern of surface-water flow. Water-table elevations, marking the top of the groundwater, show the area to be cut by two major flow divides (Figure 3.5.2). A north-south divide separates westward groundwater flow into the Hylebos Creek and Lower Puget Sound basins from that moving into the Green River valley; it lies east of I-5 and follows closely the eastern boundary of the Hylebos Creek-Lower Puget Sound drainage basin. The groundwater divide between southward flow into Puget Sound by way of Hylebos Creek and northward flow directly into Puget Sound largely follows the northern basin boundary of the Hylebos Creek basin, with the most pronounced demarcations just south of Mirror Lake and near the County line about 2 miles south southeast of Twin Lakes.

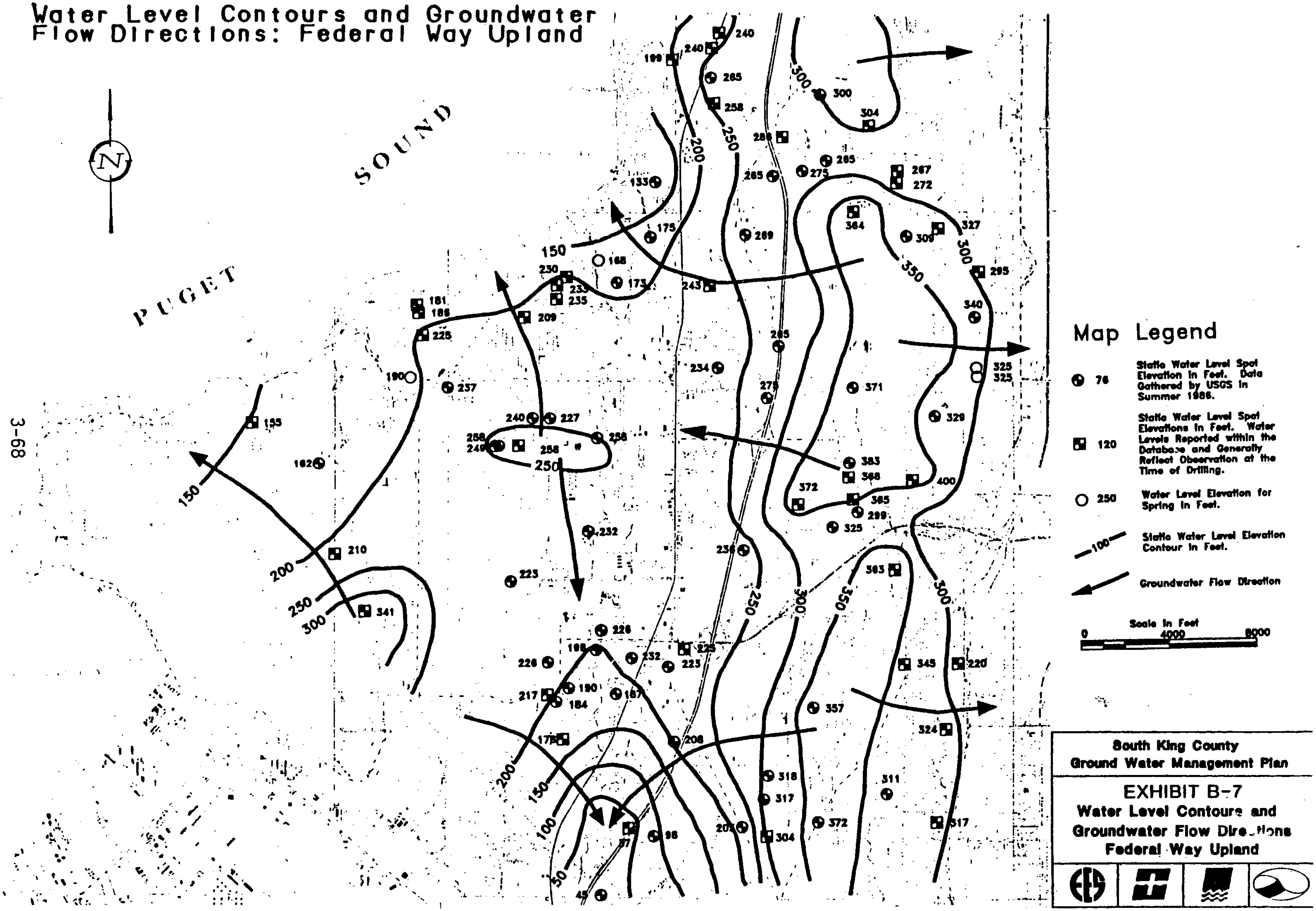
The present data are too sparse to definitively specify zones of recharge over the basin as a whole. Steep gradients in the water-table elevation suggest recharge near the groundwater divide south-southeast of Twin Lakes and along the eastern basin boundary in the area from North Lake to Fivemile Lake. "Windows" into the Vashon advance outwash, through the overlying till, along tributaries 0388 and 0389 lie at elevations far above the regional water table, and so these areas may be significant recharge zones as well. Conversely, strong discharge is suggested in the vicinity of Lower Hylebos Creek, where groundwater flow from the entire basin apparently converges in much the same pattern as the surface-water discharge.

Recharge of aquifers through the overlying Vashon till is enigmatic over the region as a whole. Measured permeabilities through till are typically about 4 orders of magnitude (10,000 times) smaller that through outwash (Olmstead, 1969) and allow recharge of only about 1 inch per month. Yet the broad areal extent of the till, and the possibility that fractures and sandier zones may allow substantially greater recharge rates in more localized zones, suggest that this path of groundwater migration may be as, or more, important than the areas of direct surface exposure of aquifers.

Other recharge zones are associated with the thinner, uppermost aquifer that overlies the Vashon till, mainly the Vashon recessional outwash. Although broad areas of this outwash are exposed on the southern uplands of the Lower Puget Sound basin, that area is largely covered with roads and houses. As a result, recharge is probably lower than would otherwise be anticipated. The southern

Figure 3.5.2

Water Level Contours and Groundwater Flow Directions: Federal Way Upland



extension of this deposit, however, forms a fairly discrete channel of thicker deposits through the Panther Lake area and into the West Branch Hylebos Creek. Although of uncertain importance for the recharge of deeper aquifers used for water supply, this deposit has functioned in the past to substantially reduce and locally eliminate the surface-water discharge of the surrounding areas. But because it is a surface aquifer, it is extremely susceptible to surface impacts. Most recently, the inwashing of fine sediment, probably released from surrounding construction activity, has severely reduced the infiltration capacity of this deposit and thus increased the amount of surface-water runoff (see Section 3.3, Hydrology).

EFFECTS OF WATER-SUPPLY PUMPING

Quantitative analysis of groundwater changes, particularly the impacts of pumping for drinking-water use, is limited by the absence of a groundwater model for this area. Only semi-quantitative methods, averaged over the area as a whole, are available to provide any such information. In addition, some historical information on water yields, water-table levels, and base flows in streams provide some additional evidence for past and future changes.

Most basic, and most common, of those semi-quantitative methods is the water balance. This method seeks to compare the amount of annual precipitation falling on the basin with the amount of surface-water runoff leaving the basin as stormflow, correcting for the amount of water presumed to annually evaporate. The residual of these surface and evaporative losses is assumed to be "groundwater recharge", which in turn is discharged via baseflow to streams, lakes, subsurface flow out to Puget Sound, and pumping for water supply. These elements of the hydrologic cycle are linked; an increase in stormflow due to increased impervious area decreases the residual water available for groundwater recharge, and an increase in pumping decreases the amount of water available for baseflow to streams.

There is no consensus on the percentage of groundwater recharge that can be removed by water-supply pumping before "unacceptable" impacts to surface-water bodies occur. This uncertainty reflects our fundamental ignorance on the quantitative aspects of groundwater movement in this (and, indeed, most) areas. In particular, monitoring data on withdrawal impacts is very spotty, a groundwater model to demonstrate surface-water connections is not available, and no analysis of surface-water conditions has yet established the framework for evaluating the consequences of any such impacts.

Relative to other regions, this basin area has rather good information on both water balance and pumping impacts. Recharge is estimated to vary between 15 to 17 inches per year (measured as a water volume of that thickness over the entire basin area; an undetermined error factor to this estimate should also be included). Of that recharge, about 15 percent was removed by water-supply pumping in 1977, but about 50 percent is now being extracted. The impacts of that increased extraction have been best documented at the pumping wells themselves, with water-table declines of up to 50 feet of decline in an isolated aquifer near Mirror Lake 10-12 feet in the main Vashon advance outwash aquifer. In addition, baseflow into Coldbrook Springs near Redondo (on Cold Creek), probably fed by this aquifer, now has greatly reduced discharge, once reported as 3.3 cfs but now less than 1 cfs; and Hylebos Creek, reported in 1969 to have a baseflow of 8.5 cfs, showed levels of only 3 to 5 cfs during the summer months of gaging in this basin in water years 1987 and 1988. Equivalent or increased future pumping from the aquifers in this area are likely to have similar or increasing impacts on the surface-water bodies in these basins.

KEY FINDINGS

- As a result of many years of investigation, the quality of information on aquifers and groundwater movement in the plan is quite high by regional standards. Recognition of the need for yet additional information is also strong in both the public and private sectors.

- Shallow aquifers provide significant attenuation of storm peaks but are susceptible to either paving or clogging, either of which dramatically reduces their ability to absorb and later discharge water.

- Zones of groundwater recharge to deeper aquifers are only modestly well-correlated with the surface exposure of those deposits.

- The risk of deep groundwater contamination is limited by the degree to which such aquifers are exposed at the surface.

- Historic pumping rates in the basins have produced significant, identifiable impacts to some surface-water flows. Other impacts may be equally significant but are not yet recognized. The intensity of all such impacts is likely to increase if present pumping rates persist or accelerate.

SECTION 3.6 EROSION AND DEPOSITION OF STREAM-CHANNEL SEDIMENT

INTRODUCTION

The topography and distribution of geologic deposits imposed on the Hylebos Creek and Lower Puget Sound basins by glacial activity have exerted a profound effect on the pattern and processes of runoff. The central upland plateau collects water over much of the basin in low-gradient stream channels. Those channels of the Hylebos Creek basin flow south, following one of two distinct paths. The West Branch follows the course of a major recessional outwash channel, formed by outflow from the retreating Vashon-age ice sheet. In contrast, the East Branch drops precipitously off the edge of the upland plateau into a narrow canyon. The drainages of the Lower Puget Sound basin are similar to the East Branch Hylebos Creek, in that their present flow paths also drop abruptly off the edge of the plateau.

DATA GATHERING METHODS AND ANALYSES

Field Data

Information in this section was derived from a variety of sources. All stream channels were walked in 1986 and 1987 during the Basin Reconnaissance Program (King County, 1987) and again in 1988-1989 for this report, in order to collect data on zones and severity of erosion and sedimentation. Although channels throughout both basins were investigated, only limited field work and no additional analysis was performed on Lower Hylebos Creek. Throughout the rest of the basins, the average width and depth of the "bankfull" channel, as expressed by the location and height of unvegetated bars and marked changes in the channel-bank slopes, were measured. Several channel locations within the basin have been measured more precisely for the last 2 to 4 years in order to track short-term changes in width and depth. Several streams were also surveyed for their longitudinal channel profile, which allows for a rudimentary calculation of current and future sediment transport down these watercourses. The effect of projected flow increases can thus be predicted semi-quantitatively, guided and enhanced by more qualitative information generated by these other efforts.

Analysis of Channel Size

The response of stream channels to changes in land use has long been recognized (e.g., Wolman, 1967; Leopold, 1973). Quantifying the rate and magnitude of those responses, however, is more difficult. Undisturbed drainage basins commonly yield consistent relationships between discharge or drainage area and the channel width and depth (cf. Dunne and Leopold, 1978). The increase in flows that accompanies urbanization in a single basin is not identical to the increase in flows between a smaller and a larger undisturbed basin, but techniques developed by study of the latter case are still useful in understanding post-development conditions.

Studies of the "hydraulic geometry " of a channel (i.e., the channel width, depth, and flow velocity; Wolman and Miller, 1953) show consistent relationships between the flow at some specific discharge and the corresponding size of the channel. In comparing the increasing size of channels lower in the drainage basin, the "bankfull" flow, defined as the flow that just fills the active channel and typically assumed to be the 1.5-year flood discharge, is commonly used as the reference discharge. Plots of channel width and depth versus that 1.5-year flow at the point of measurement commonly show a consistent relationship, not because the 1.5-year flow necessarily determines the size of the channel but because that flow is a convenient reference discharge for all of the flows that, in combination, determine channel size. This relationship can be used to predict how future changes in the stream flow may affect the resulting size of the physical channel.

Channel Incision and Erosion

Channels require several conditions in order to incise into their beds, including substantial erosivity of the water flow and absence of adequate bed armoring by relatively immobile sediment or debris. In order to make comparisons between channels or predictions about future channel conditions, these factors must be quantified as best as possible. Although factors such as bed armoring by coarse debris are difficult to define precisely, the ability of the water to transport sediment is better understood.

This transporting ability, or erosivity, of the water flow is best represented by its basal shear stress, which is the tractive force applied by the water to its bed area and which consequently moves sediment particles downstream. The shear stress is calculated as the product of the water depth and the water-surface slope, multiplied together with a constant that is the unit weight of water (i.e. its weight per some specific volume, such as one cubic foot or one cubic meter). In this report the shear stress is reported in metric units of Newtons per square meter (N/m^2), using the measured depth of the bankfull channel and calculating the slope from 1:24,000 topographic maps. Most of the lower reaches of the channels were also field surveyed to provide comparative slope data; the results of the two methods of slope determination differ only modestly in most localities and do not affect any of the conclusions of the subsequent discussions.

CONDITIONS

Overview

Two overriding conditions of the physical channels in the basin are manifest: most of the natural channels have been heavily impacted by high flows, and they also show evidence of abundant introduction of fine sediment. The first condition is particularly well displayed by the flume-like nature of many channel reaches, where the hydraulic and biologic diversity provided by pools, bars, and large debris has largely been stripped away. As a result, channel erosion, neighboring hillside erosion, and downstream deposition of channel- and culvert-clogging sediment are much higher than normal. The second condition is partly related to the first; channel erosion releases some fine sediment into the downstream system. But upland urban development, particularly construction during wet weather, generates far more of this material. These fines not only clog stream-bed sediment, affecting fish habitat, but also carry pollutants off the uplands into and through the stream system. As such, they also represent one of the major threats to water quality in the basin as well.

Stream-Channel Characteristics

The degree of downcutting and lateral erosion found along each of the major stream valleys correlates well with their location and underlying geologic deposit. Most of the channels cut into sandy deposits, primarily of the Vashon advance outwash, on their decent from the upland plateau down to Puget Sound. This deposit is recognized here and elsewhere throughout the Lowland for its ease of erosion, by virtue of its relatively fine grain size and minimal cohesiveness. These channels lie in narrow valleys and canyons created by erosion from the streams themselves, formed over the last 14,000 years. These same erosive processes can be observed on a smaller but far more rapid scale along the banks and beds of these same channels where upstream development has recently increased flows. Bank slumps, undercutting, knickpoints (vertical steps in the stream profile, typically 1 to 6 feet high, that migrate upstream over time), and sporadic hillslope failures along the valley sides all reflect this erosive activity. The processes are the same today as they have been for the last thousands of years, but the rate at which they are occurring has increased dramatically in recent times with urbanization.

The West and Lower Branches of Hylebos Creek are unique of the streams here, in flowing in a drainage course pre-established by glacial runoff of much greater magnitude than found in the streams of today. The valley so created, is up to one-half mile wide in its lower reaches and is filled with a mixture of stream-deposited and lake-deposited sediment; the modern drainage has managed to cut only short and relatively shallow valleys in localized areas. As a result, erodible older sediments are nowhere exposed along the West Branch or its tributaries, and the profile of this channel shows no abrupt changes and few reaches of significant steepness.

As a result of these characteristics, the channel is intrinsically less susceptible to erosion and its flow less competent to transport sediment. Diversion of its northern headwaters during construction of I-5, highly infiltrative areas in the northwest part of the sub-basin, and modest buffering of peak flows by the West Hylebos Wetland have further reduced impacts of basin urbanization to date. The infrequency of significant erosion problems and presence of locally high-quality aquatic habitat despite high peak flows reflect these physical characteristics.

The channels of the North and Central Lower Puget Sound sub-basins (McSorley, Woodmont, Cold, and Redondo Creeks) flow only in part over steep, sandy deposits. In this part of the basin plan area, these deposits are thin, sandwiched between the Vashon till above and fine-grained sediment below. As a result, zones of intensive stream-channel downcutting are more limited than in the neighboring drainages farther west. Hillslope failures associated with these easily saturated, groundwater-perching deposits, however, are rather common.

Changes in Hydraulic Geometry

Cross-Section Changes - Using the method of comparing measured channel dimensions with an "index" or reference discharge permits prediction of future channel conditions. The HSPF model outputs provide 2-year flows under 1987 conditions, a convenient reference discharge; bankfull channel measurements were made at 24 separate stations in the two basins during 1988 and early 1989. A relatively good relationship is plotted in Figure 3.6.1, with the equation of the best-fit line given as:

$$\text{width x depth} = 0.61\ Q(2\text{-yr})^{0.71},$$

with width and depth measured in feet and Q in cubic feet per second.

These results allow for a rapid estimate of the overall effects of future flow conditions on existing channels. In general, future flow increases will yield increased channel sizes, with more sediment produced from those channels as a result. For example, flow increases of 1.5- to 2.5-fold, typical over most of the subcatchments in the East and West Branches of Hylebos Creek under future conditions without mitigation, yield a predicted channel expansion of 33 to 90 percent over existing conditions.

Where previous flows are anticipated to increase even more dramatically, the changes in the channel are even more pronounced. For example, flows from Panther Lake into the West Hylebos Wetland (tributary 0014B in subcatchment WH7; see Figure 4.2.1) are predicted to increase almost 9-fold under future conditions without mitigation. This would result in a predicted 4.6-fold increase in channel size. Interestingly, some of this channel expansion appears to have already occurred, probably reflecting substantial flow increases in this tributary since model calibration in 1987 (see Section 4.2, West Branch Hylebos Creek Sub-basin). Figure 3.6.2 plots the data from all measured channel sections together with the data from the channel connecting Panther Lake to the West Hylebos Wetland, measured in the vicinity of 1st Avenue S in 1989. The misfit between 1987-predicted flows, when Panther Lake was functioning as an efficient infiltration basin, and 1989, when the channel measurement was made and the basin had already been severely affected, is obvious. These results suggest that the channel is already experiencing flows about twice what is predicted under 1987 conditions. They also imply that more than half of the total future channel expansion has yet to occur.

Depth and Shear Stress Changes - An analysis equivalent to that above for cross-sectional area can be made for changes in channel depth alone. The relationship is not as consistent as for cross-sectional area, because local variability in channel conditions may lead to equally local increases or decreases in the depth at the expense of the width. The relationship is plotted in Figure 3.6.3, with the best-fit line given by:

$$\text{depth} = 3.1\ Q(2\text{-yr})^{0.27},$$

with all units again in feet and cubic feet per second.

The depth of the bankfull channel alone is not terribly sensitive to flow increases. For example, a 2-fold increase in the 2-year discharge yields only a predicted 20-percent increase in the bankfull channel depth.

This change can be used to calculate shear stress changes and to predict changes in stream erosivity. Based on field measurements and equivalent analyses in the Soos and Bear Creek basins (reported in Booth, 1989b, 1990b, in press b), observable erosive conditions in these lowland streams become common at a shear stress (based on the bankfull channel depth) of about 85 N/m^2. The threshold is quite distinct; in measuring and observing erosive conditions along over 50 miles of stream channels in these 2 other basins, only about 5 percent of the total length was mis-categorized by this sole criterion (Booth, in press b).

Figure 3.6.1

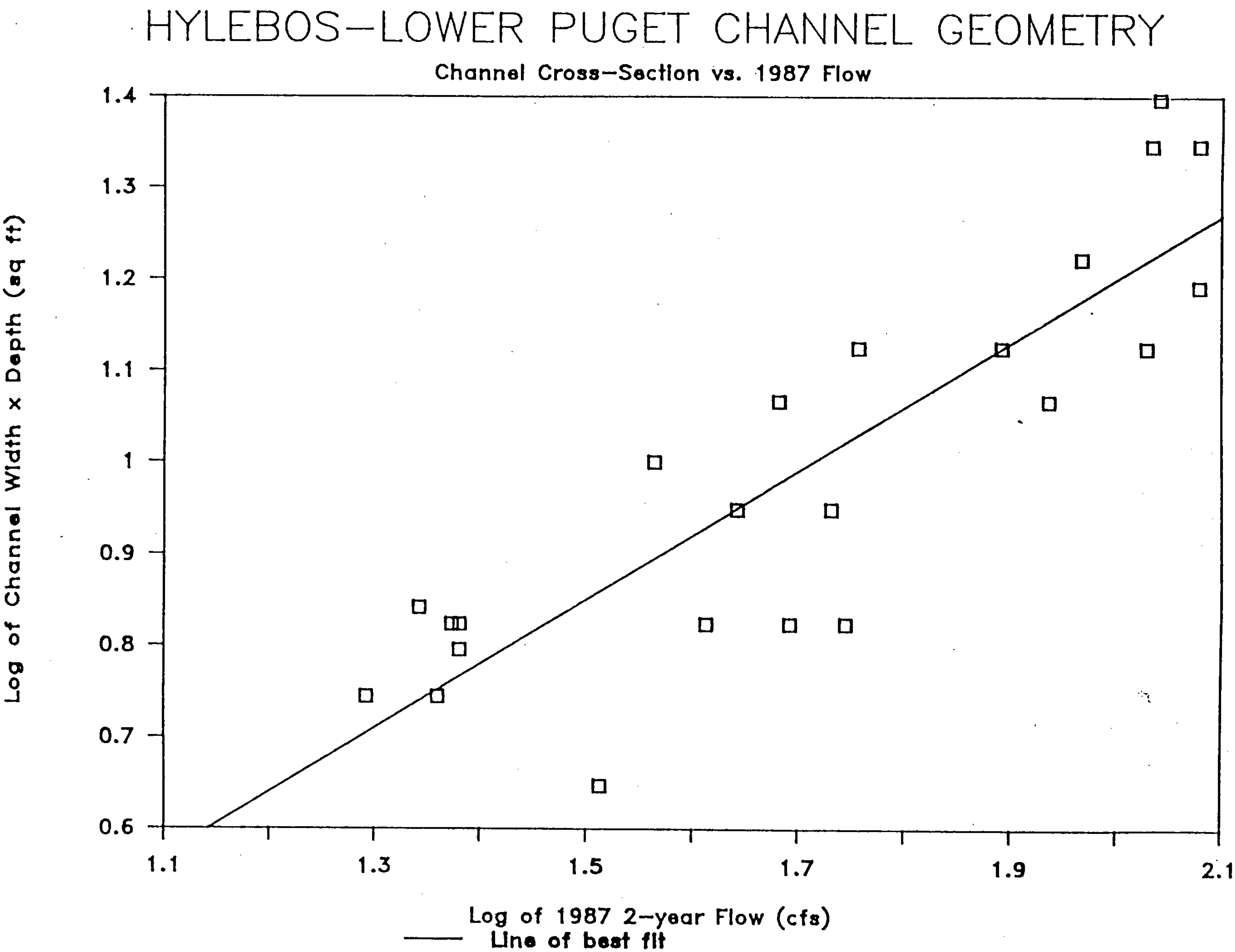

HYLEBOS–LOWER PUGET CHANNEL GEOMETRY
Channel Cross–Section vs. 1987 Flow
Log of Channel Width x Depth (sq ft)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
1.1
1.3
1.5
1.7
1.9
2.1
Log of 1987 2–year Flow (cfs)
Line of best fit

Figure 3.6.2

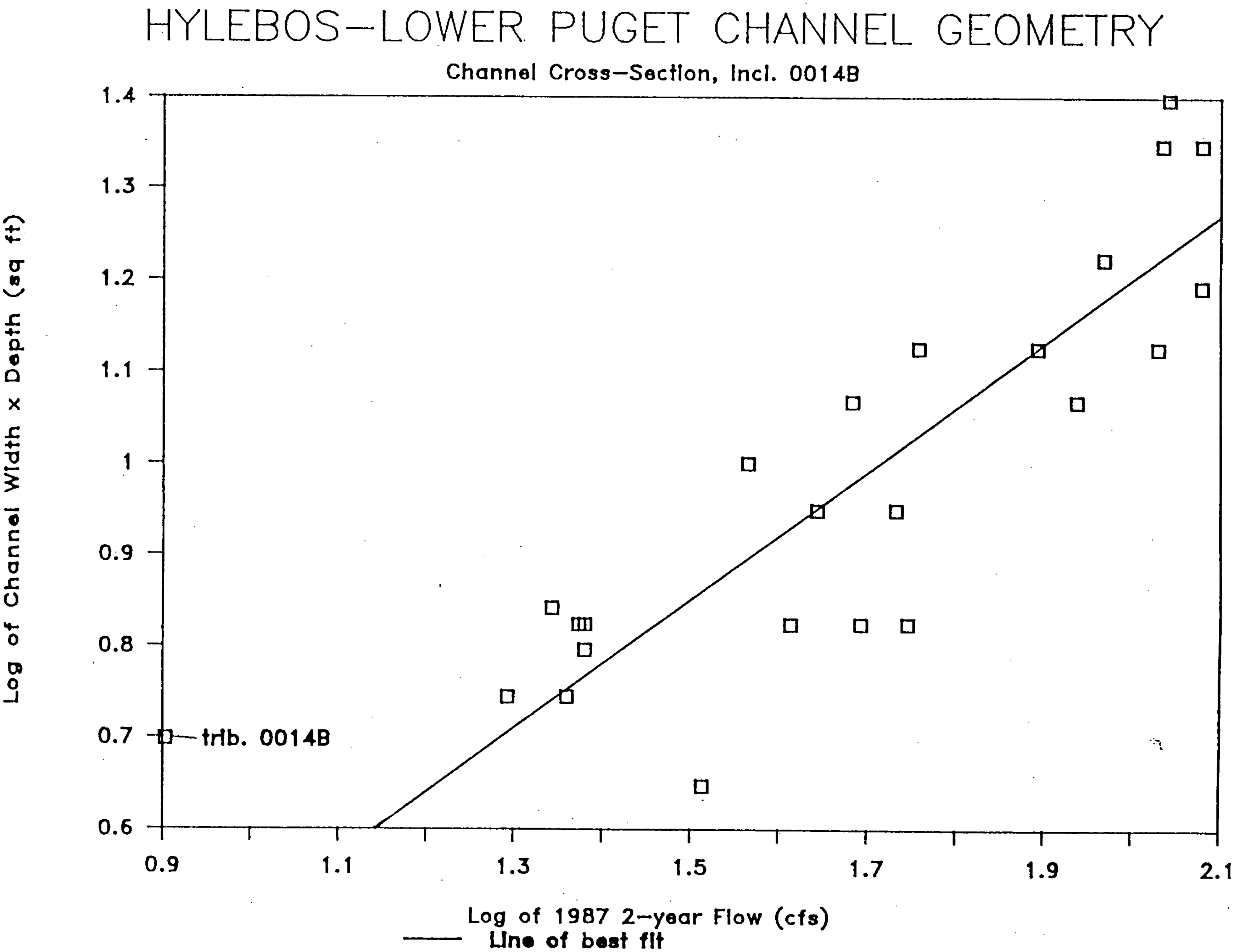
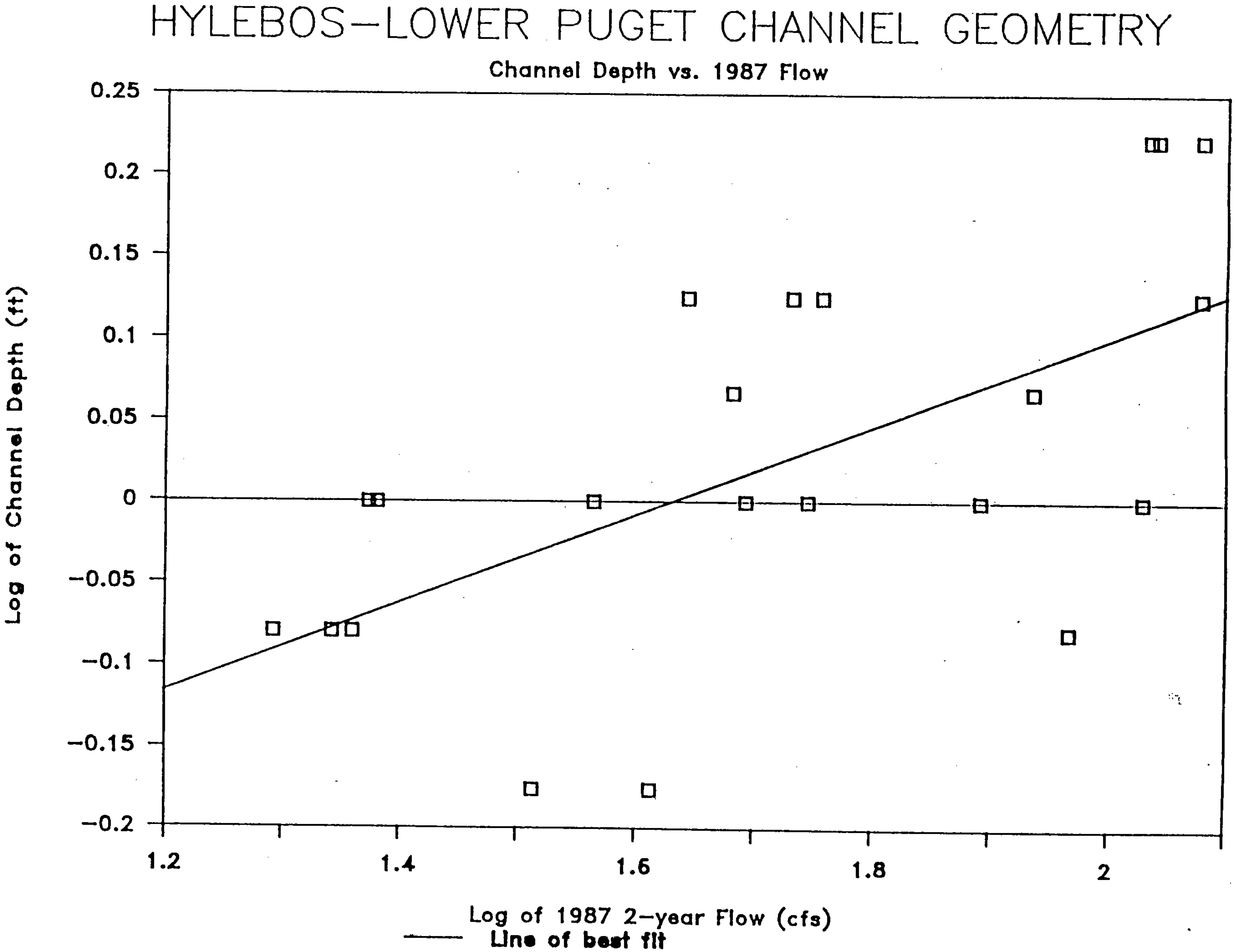

HYLEBOS-LOWER PUGET CHANNEL GEOMETRY
Channel Cross-Section, Incl. 0014B
Log of Channel Width x Depth (sq ft)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
trib. 0014B
0.9
1.1
1.3
1.5
1.7
1.9
2.1
Log of 1987 2-year Flow (cfs)
Line of best fit

Figure 3.6.3


HYLEBOS-LOWER PUGET CHANNEL GEOMETRY
Channel Depth vs. 1987 Flow
Log of Channel Depth (ft)
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
1.2
1.4
1.6
1.8
2
Log of 1987 2-year Flow (cfs)
Line of best fit

This threshold level has been confirmed in this basin as well, although the sources of slope data are not as uniformly good as in the Soos and Bear Creek examples. Figures 3.6.4 and 3.6.5 plot the stream profiles of the Hylebos and Lower Puget Sound drainages in their lower and middle reaches, together with lines showing the threshold of channel erosivity for various values of depth and slope. For example, channel reaches more steep than the "depth=1 ft" line will experience a shear stress at bankfull flow of greater than 85 N/m^2 if their bankfull channel depth is greater than or equal to 1 foot. Similarly, as the channel slope decreases, greater depths can be tolerated without that "erosivity threshold" being crossed.

Presently, only a few of the plotted channel reaches fall under the 85 N/m^2 threshold. These include the West Branch Hylebos Creek up to the northern edge of the glacial-age lake bottom (tributaries 0013 and 0014; see Figure 4.2.1), the undiverted part of tributary 0013 on the flat till uplands and the equivalent segment of tributary 0014 through the West Hylebos Wetland, part of the lower-most reaches of Saltwater Creek (0381), parts of Lakota Creek just below its main confluence (0386), and parts of Joes Creek about 0.5 miles downstream of SW 320th Street (0388). All measured parts of the East Branch Hylebos Creek (0006, 0015, and 0016; between the County line and SR 161) lie above this threshold.

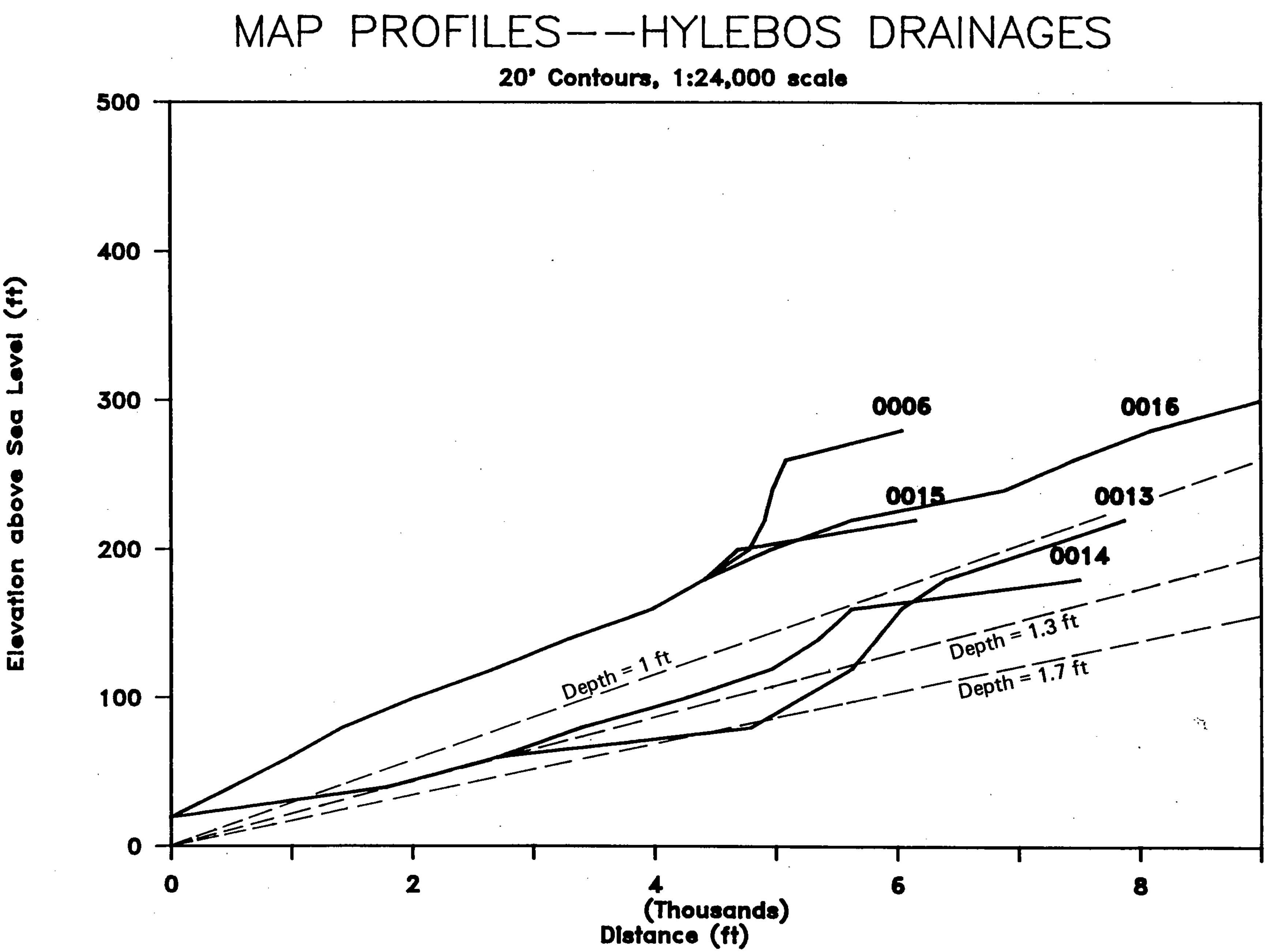
Conditions in the Hylebos Creek and Lower Puget Sound channels can be compared with these graphs to validate the assumption of a threshold value. Observation made prior to the storm of January 9, 1990 confirm this predicted distribution of largely "non-erosive" reaches (see Chapter 4 for specific discussions). In those reaches, where impacted by that January storm, subsequent lower flows are anticipated to rebuild and restore a relatively undamaged stream channel.

Future flow increases may eliminate some of this restorative ability. The erosivity of all flows will increase, by increasing their depth. This analysis considers only changes in the peak magnitude, although the duration of those flows will also change as a result of further development. As such, it may underestimate the effects of urbanization on these channels but by an indeterminate amount.

Using the relationship displayed in Figure 3.6.3, bankfull channel depths should increase proportionally to 2-year flow increases raised to the 0.27 power. This is not a terribly strong relationship, but it is adequate to increase the predicted bankfull shear stress without mitigation of the West Branch Hylebos Creek from a "non-erosive" to "erosive" condition over an additional 0.6 miles along tributary 0014 in the vicinity of its confluence, both upstream and downstream, with tributary 0013. Upper 0013 is also predicted to roughly equal that threshold under future flow conditions. None of the "non-erosive" zones in the Lower Puget Sound drainages change fundamentally, mainly because the basins are already substantially built-out and anticipate only moderate future flow increases.

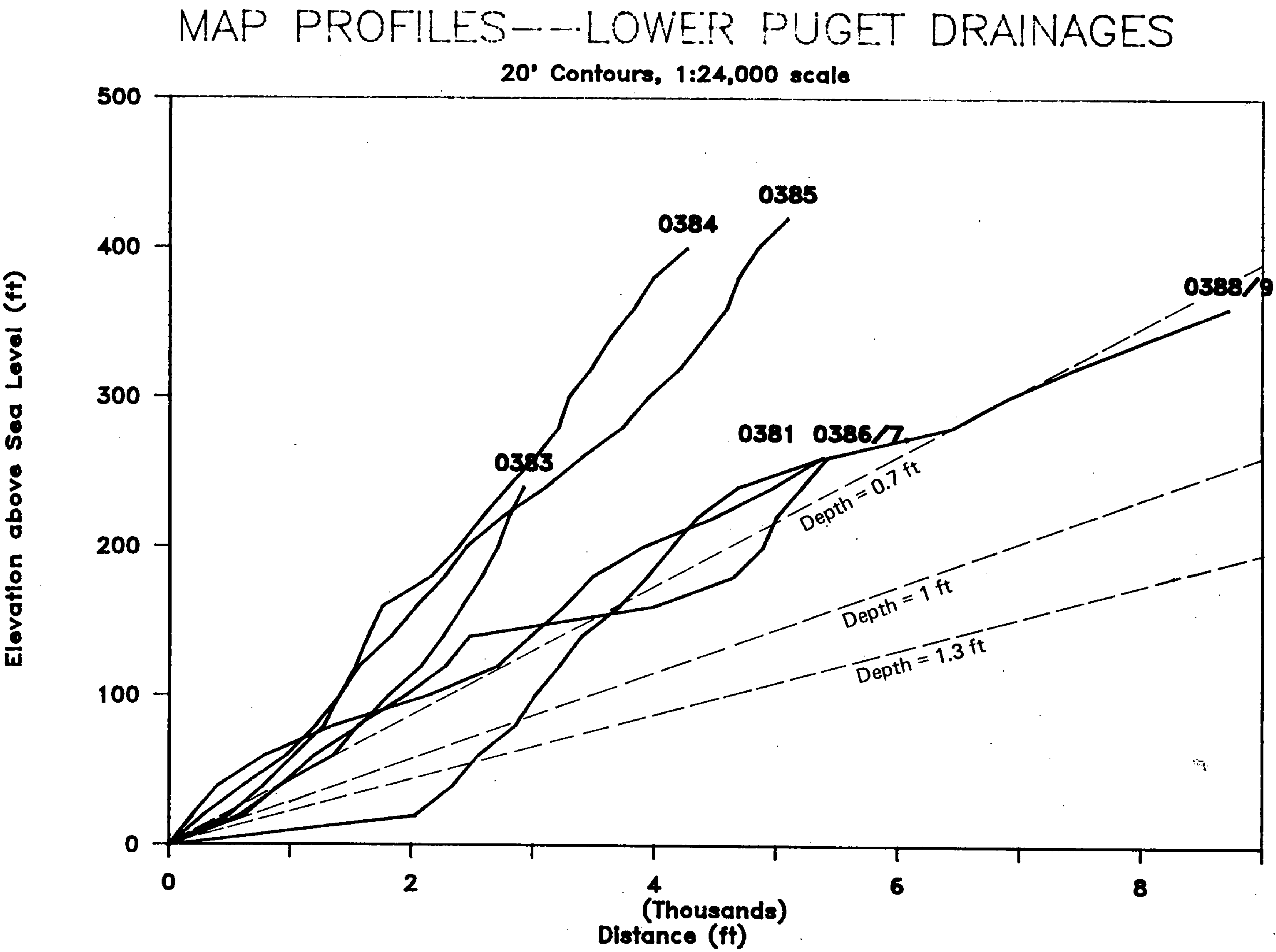
Stream-Channel Incision - Incision differs from simple channel expansion by its magnitude and by its relationship to the flows that cause it. Whereas increases in the bankfull depth or width reflect a proportional increase in the flows that form the channel, incision reflects a disequilibrium entrenchment of the channel bed. A "bankfull channel" may still exist through an incised reach, but it lies at the bottom of a recently entrenched ravine or canyon of far greater significance to the system as a whole.

Figure 3.6.4



MAP PROFILES--HYLEBOS DRAINAGES
20' Contours, 1:24,000 scale
Elevation above Sea Level (ft)
500
400
300
200
100
0
0
2
4
6
8
(Thousands)
Distance (ft)
0006
0016
0015
0013
0014
Depth = 1 ft
Depth = 1.3 ft
Depth = 1.7 ft

Figure 3.6.5


MAP PROFILES--LOWER PUGET DRAINAGES
20' Contours, 1:24,000 scale
Elevation above Sea Level (ft)
500
400
300
200
100
0
0
2
4
6
8
(Thousands)
Distance (ft)
0383
0384
0385
0381
0386/7
0388/9
Depth = 0.7 ft
Depth = 1 ft
Depth = 1.3 ft

Although adequate erosivity of the flow is one of the necessary conditions for channel incision, other factors are also necessary. The channel must lack large organic debris or sediment that would otherwise dissipate some of the flow energy. The water must flow over a substrate that is itself easily eroded and not cemented (thus excluding, for example, unweathered till). The channel must also lie well above its "base level", namely the elevation below which it cannot fall (Puget Sound, for example, or a fixed culvert inlet). If base level lies nearby, an incising stream will rapidly reduce its overall slope as it downcuts, reducing its erosivity and so limiting its own further activity. If, on the other hand, base level is so far downstream that a local bed lowering does not noticeable change the overall channel slope, further erosion will continue unabated.

The combination of little immobile debris, easily eroded bed material, and distant base level, is achieved along several channel reaches in these basins. Most pronounced of these are found along the tributaries of East Branch Hylebos Creek (0006, 0015, and 0016 below SR 161), where high discharges flowing over deposits of the Vashon advance outwash have yielded recent examples of substantial channel incision and knickpoint migration. Damage from the January 9, 1990 storm in these tributaries is among the most dramatic countywide. Similar substrate conditions are located along the drainages of the South Lower Puget Sound sub-basin, although the proximity of Puget Sound reduces the possibility of significant downcutting. Yet the valley walls are also very susceptible to erosion from increased flows, yielding observed problems of sideslope landsliding and bank failures that reflect these physical conditions. Elsewhere, most of the channel lengths of the Lower Puget Sound drainages flow over relatively unerodible sediment, and so their associated problems are comparatively less despite their greater slopes.

Deposition - Both channel expansion and channel incision yield sediment, which in turn must come to rest farther downstream in the system. Just as increasing erosivity and transporting ability are marked by increased flow depth or slope, so a reduction in transporting ability is caused by reductions in these parameters. The most significant reductions are typically in the slope, and they generally occur where either the overall gradient of the landscape, and thus the stream channel flowing over it, flattens. Over many millennia, erosion and deposition tend to "smooth" the stream profile to allow efficient delivery of the entire sediment load to the mouth of the river; but the channels here in the basin plan area are relatively young and are still strongly affected by the glacial topography. They are also affected by local constrictions and backwaters from bridges and culverts, which tend to focus and so amplify any regional patterns of deposition.

The most profound flattening in the area occurs near the base of the Hylebos Creek basin, as the East and West Branches descend off the till-covered upland plateau onto the late-glacial lake bed near the County line. Coarse sediment is deposited first, followed by progressively finer material as the gradient drops progressively downstream. The deposition of sediment in this area is inescapable; the amount of sediment so deposited, however, will depend critically on the magnitude of erosion by upstream flows. Because of the magnitude of upstream erosion, deposition here is presently noteworthy not only across these two basins but also countywide.

KEY FINDINGS

- The West Branch Hylebos Creek is intrinsically more resistant than the East Branch to urbanization effects by virtue of channel gradient, past diversions, and some upstream hydraulic buffering. Individual tributaries however have experienced dramatic incision from development-increased runoff.

- Erosion susceptibility of tributaries in the North and Central Lower Puget Sound sub-basins is lower than in the South sub-basin, where channel incision has been locally substantial.

- Deposits of the Vashon advance outwash are particularly susceptible to stream-channel erosion, as demonstrated along Lakota Creek, Joes Creek, and East Branch Hylebos Creek.

- Increases in future flows will cause significant expansion of most channels, which in turn will result in substantial transport and downstream deposition of sediment.

- Deposition of sediment is particularly favored, and the resulting problems particularly significant, in the vicinity of the confluences of West Branch, the north fork of the West Branch, and East Branch of Hylebos Creek.

- Fine sediment commonly cements gravel beds throughout the basins, derived in significant measure from construction activity on the till uplands.

- The channel of tributary 0014 in the vicinity of its confluence with 0013, and much of 0013, will likely experience significant increases in the intensity of erosion under future flows without mitigation.

- Incision of the East Branch Hylebos tributaries downstream of SR 161 is presently among the most active county-wide and will likely accelerate further under predicted future flow increases.

SECTION 3.7 WATER QUALITY

INTRODUCTION

Past monitoring provides an incomplete picture of water quality in the Hylebos Creek and Lower Puget Sound basins. There exists very little scientific or engineering data describing the nature of nonpoint pollution and its effects on the streams, lakes, and the Puget Sound shoreline within the Federal Way Community (Minton, 1985).

This section includes a description of the water quality studies in the planning area, criteria for determining significant conditions; a description of current conditions during both baseflow and storm event periods; and implications for future water quality conditions.

WATER QUALITY CONCEPTS

Physical Conditions That Affect Water Quality

The northern portions of the Hylebos Creek basin are highly urbanized and are currently (1987) dominated by one of three types of land uses: commercial, high density single family, and multifamily. These types of land uses are relatively high in impervious areas and have been shown to concentrate and transport significant pollutant loads to surface waters. In addition, two major highway systems (State Route [SR] 99 and Interstate 5 [I-5]) dissect the basin. These large volume traffic corridors are significant sources of nonpoint pollutants in this basin. Five lakes (North, Weyerhauser, Killarney, Brook, and Panther) also characterize the upper reaches of the basin. These lakes can act either as "sinks" (i.e., trapping incoming pollutants such as nutrients) or as "sources" of pollutants such as nutrients. The middle and lower reaches of the Hylebos Creek basin are bordered by relatively large wetlands and forested areas as well as some agricultural lands. Poor agricultural practices such as those allowing livestock unlimited access to creeks, excessive fertilizer/pesticide applications, failing sewage systems, and overgrazing of pastures can contribute significantly high levels of pollutants to surface waters and receiving bodies.

The Lower Puget Sound basin is dominated by high-density single-family residences on the plateau areas that drain to steep ravines and easily eroded lower channel reaches. As a result, high volumes of eroded sediment are common. Contaminants (such as, phosphorus, some metals, and to some degree fecal coliform organisms), originating from residential land areas, tend to adhere to these sediments and can contribute significant pollutant loadings to receiving waters such as Puget Sound. Pollutant loadings can be defined as streamflow multiplied by a particular pollutant concentration. Pollutant loadings can become significant when receiving waters such as lakes (e.g., Steel Lake, Mirror Lake, Lorene Lake, and Jeane Lake) cannot flush contaminants. However, when the receiving water is Puget Sound, there is usually a large dilution factor in mixing zone areas (i.e., where freshwater systems meet marine waters) and pollutant loading is not a large concern except where water supplies and recreational shellfish harvesting are locally important beneficial uses.

Criteria for Determining Significant Conditions

Chapter 173-201 of the Washington Administrative Code (WAC) contains water quality standards for surface waters of the State of Washington. The purpose of Chapter 173-201 is to establish water quality standards for surface waters of the State consistent with public health and public enjoyment and the propagation and protection of fish, shellfish, and wildlife.

Waters within both the Hylebos Creek and Lower Puget Sound basins are classified as Class A (Excellent). State water quality standards require that water quality with Class A waters meet or exceed the requirements for all or substantially all beneficial uses. Characteristic uses include, but are not limited to the following:

- Water supply (domestic, industrial, agricultural)
- Stock watering
- Fish and shellfish (migration, rearing, spawning, and harvesting)
- Wildlife habitat
- Recreation (swimming, sport fishing, boating, and aesthetic enjoyment), and
- Commerce and navigation.

Washington State has established water quality criteria for fecal coliform densities, dissolved oxygen, temperature, pH, and turbidity. Other variables such as key nutrients (e.g., nitrogen and phosphorus) do not have state water quality criteria established due to the large variability among water bodies and their drainage basins which may have large differences in soil type and land use (e.g., highly erosive versus non-erosive or rural versus urban).

In some instances, other agencies have set recommended guidelines (e.g., EPA criterion for total phosphorus) to prevent the development of biological nuisances and to control accelerated or cultural eutrophication, or State Board of Health Drinking Water Regulations maximum contaminant levels for inorganic chemical characteristics. Table 3.7.1 lists the current State and/or federal water quality criteria/recommendations. For two variables (nitrate + nitrite - nitrogen, and total suspended solids) no state criterion exists. For the purpose of this report, a basin plan "threshold value" was set to allow comparison of sub-basins and identifying problem areas. These threshold values (although highly subjective) were arrived at by reviewing other study results, monitoring experience, and King County SWM water quality staff professional judgement.